EFFECTS OF ALL-TERRAIN VEHICLE USE IN THE VICINITY OF ANAKTUVUK PASS, GATES OF THE ARCTIC NATIONAL PARK, ALASKA: I. STUDY OF ESTABLISHED, RECOVERY, AND NEW TRAIL SEGMENTS

by

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CONVERSION FACTORS

English System Equivalents for Metric Units

Centimeter (cm) - 0.3937 inch

Gram (gm) - 0.035274 ounce (avoirdupois)

Kilogram (kg) - 2.2046 pounds (avoirdupois)

Kilometer (km) - 0.62137 mile

Meter (m) - 1.0936 yards; 3.2808 feet; 39.3700 inches

Square centimeter (cm^2) - 0.1550 square inch

Metric System Equivalents for English Units

Foot - 0.3048 meter; 30.48006 centimeters

Inch - 2.540005 centimeter

Mile - 1.60935 kilometers

Ounce (avoirdupois) - 28.34953 grams

Pound (avoirdupois) - 0.4535924 kilogram

Pounds per square inch - 70.0307 grams per square centimeter

Square inch - 6.451626 square centimeters

Yard - 0.9144 meter

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INTRODUCTION

Use of all-terrain vehicles (ATV) by residents of Anaktuvuk Pass, Alaska, a village that lies within Gates of the Arctic National Park, for access to traditional subsistence resources has increased rapidly over the past few years as vehicles have become more numerous in the village. The effects of this activity on vegetation and soils have become increasingly evident in all directions leading from the village. In only a few years time this has resulted in an extensive trail system that continues to expand.

All-terrain vehicle use on park lands is generally prohibited, however, several easements exist on non-wilderness park lands that permit village residents access to traditional subsistence resources by motorized means. Many residents are not satisfied with the easements and have asked for unrestricted, dispersed ATV use within the valleys through which the easements run and in certain nearby portions of wilderness. They claim that dispersed ATV use will cause no long-term adverse effects as happens when travel is restricted to relatively narrow designated routes.

The major vehicles in use on the trails at the time of the study were six-wheel and eight-wheel drive amphibious Argos (Ontario Drive and Gear Limited, New Hamburg, Ontario, Canada). These vehicles are 1.5 m wide, have 20 cm of clearance on flat ground, range in weight from 330-434 kg, and have a 227-445 kg carrying capacity. They were equipped with 28 cm wide, low pressure, webbed tires (either Runamuck or Rawhide design). The ground pressure of each tire on an Argo equipped with Runamuck design tires normally ranges from 130-310 g cm^{-2}.

Field research was initiated during the summer of 1986 to study the effects of ATV use under normal conditions on several types of terrain in areas where travel restrictions had been eased or lifted. The research was divided into three separate, but related projects: (a) a study of the effects of repetitive ATV use on established, recovery, and new segments of trails; (b) a multiyear program of aerial photography for documenting the extent of ATV trails in the area; and (c) a study undertaken by Gates of the Arctic personnel to document the effects of dispersed ATV use in places where it was known to have occurred. This report summarizes the results of research conducted during the 1986 and 1987 field seasons to quantify the effects of repetitive ATV use in the vicinity of Anaktuvuk Pass and completes (a) above. The aerial photography and dispersed use projects will be the subjects of additional reports.

STUDY AREA

Anaktuvuk Pass has a population of approximately 250 people. The village is located 75 km north of the Arctic Circle and lies on the continental divide of the Central Brooks Range. The Anaktuvuk River serves as the principal drainage for the area north of the pass, while the John River drains the area to the south.

Thirteen ATV trail study sites were selected near Anaktuvuk Pass (Fig. 1) in tundra community types representing a spectrum of moisture conditions (Table 1). The sites occurred in plant communities typical of those traversed by ATVs and were

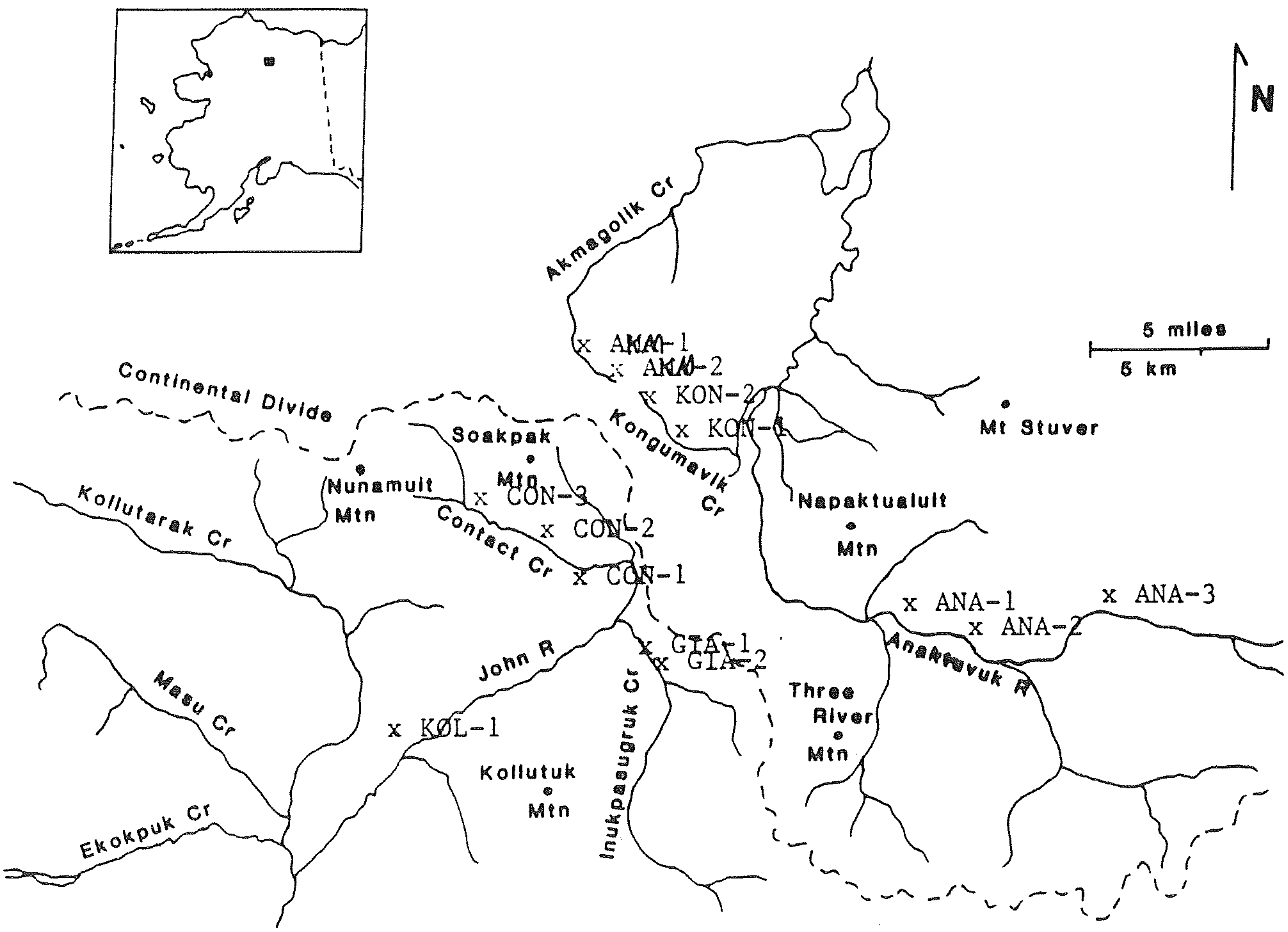

Fig. 1. Location of Anaktuvuk Pass ATV study sites.

Table 1. Characteristics of the ATV research sites.

Site	Elevation (m)	Slope (%)	Aspect	Plant Community Type*	Moisture status
AKM-1	955	4	NW	Willow-sedge shrub tundra	Moist
AKM-2	940	2	N	Dryas-sedge dwarf shrub tundra	Moist-wet
ANA-1	680	0	-	Dryas-lichen dwarf shrub tundra	Dry
ANA-2	715	0	-	Dryas-lichen dwarf shrub tundra	Dry
ANA-3	695	0	-	Dryas-sedge dwarf shrub tundra	Wet
KON-1	820	22	NE	Dryas-sedge dwarf shrub tundra	Dry
KON-2	985	12	NE	Dryas-sedge dwarf shrub tundra	Dry-moist
CON-1	820	0	-	Dryas-sedge dwarf shrub tundra	Dry
CON-2	850	10	S	Dryas-sedge dwarf shrub tundra	Moist-wet
CON-3	880	0	-	Dryas dwarf shrub tundra	Dry
GIA-1	665	0	-	Open low willow shrub	Dry
GIA-2	695	4	W	Open low mixed shrub-sedge tussock tundra	Moist-wet
KOL-1	630	6	E	Dryas dwarf shrub tundra	Dry

*Classification follows Viereck et al. 1986.

distributed among the drainages of the Anaktuvuk River (AKM 1-2); and Kollutarak (KOL-1), Contact (CON 1-3), Kongumavik (KON 1-2), Akmagolik (AKM 1-2), and Giant (GIA 1-2) Creeks. Kongumavik and Akmagolik Creeks drain into the Anaktuvuk River, while the others flow into the John River.

Both Akmagolik sites were located in the upper reaches of Akmagolik Creek. AKM-1 was near the headwaters and AKM-2 was approximately 0.4 km downstream just before the creek enters a broad open area and changes course from northwest to northeast. All Anaktuvuk sites were situated on the north side of the river.

ANA-1 was on an old river terrace or stabilized floodplain, while ANA-2 was on an old moraine bluff above the river, and ANA-3 was located in a wet flat between the river and the base of a steep slope. KON-1 was established on a steep rocky slope above Kongumavik Creek. The KON-2 site was situated on a slope above Kongumavik Creek and was dissected by a small tributary stream. Low shrubs and some tussocks (open low mixed shrub-sedge tussock tundra) occurred on the lower side of the stream crossing at this site. CON-1 was placed on a stabilized floodplain and CON-3 was on a terrace above Contact creek. CON-2 was at the base of a steep slope on poorly drained soil with water running across portions of the trail. GIA-1 was located on a terrace above Inukpasugruk Creek and GIA-2 was on a gentle slope leading to the creek. KOL-1 was established on a very rocky kame terrace.

METHODS

Field Procedures

Conditions at each site were studied along 30 m segments on an established and used portion of trail (established), on an established but closed portion of trail (recovery), and on a newly established portion of trail (new) routed parallel to the closed, recovery portion. We relied upon the advice of Paul Hugo, a resident of Anaktuvuk Pass, in selecting the established, recovery, and new segments at each field site. He was especially helpful in choosing new segments that were likely to be used. Slope, aspect, elevation and major plant species were recorded for each site.

Three transects were established perpendicular to the trail at the 5, 15, and 25 m points along each 30 m segment (Fig.2). An elastic cord and tape measure were stretched between stakes which were driven into the ground beyond the ends of each transect. Surface profiles were obtained along a 4 m transect centered over the tracks by measuring the distance from the cord to the ground at 5 cm intervals with a meter stick (Fig 3). Six 20 X 50 cm plots were sampled along each transect using a frame at intervals selected to divide the plots evenly between vegetation growing between (between tracks treatment), within (track treatment), and outside (outside track treatment) the tracks (total of 18 plots per treatment, 54 plots per site). Species included within or overlapping the plot frame were recorded according to one of six cover classes with midpoint cover percentages of 2.5, 15, 37.5, 62.5, 85, and 97.5 (Daubenmire, 1968). In order to document change over time, measurements on the transects were repeated several times throughout the summer. Species cover tended to increase over the course of the summer due to normal plant growth and more than compensated for, in most cases, any decreased coverage attributable to ATV traffic. Therefore, the plot data were used only for the purpose of classifying vegetation communities.

Vegetation types were determined for each site using species coverage data obtained early during the 1986 field season. Data for all new segment and control (outside track) plots for recovery and established segments were used to classify

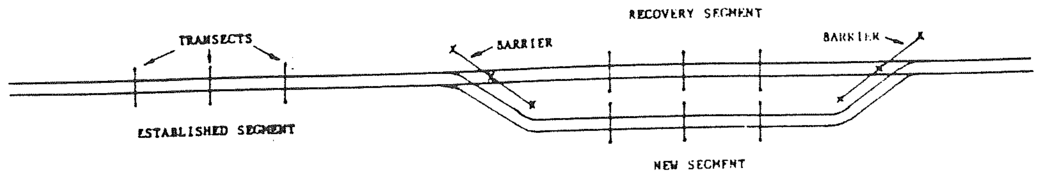

Fig. 2. Typical arrangement of transects on site study segments.

undisturbed vegetation for each site. Coverage by species for plants growing on disturbed areas (tracks) was based on data from track plots of recovery and established segments. Nomenclature follows Thompson (1984) for lichens, Crum and Anderson (1981) for mosses, Viereck and Little (1972) for shrubs, and Hulten (1968) for all other vascular plants.

A rating scale (Table 2) was devised to evaluate the ATV tracks in each 30 m segment. These ordinal data are useful for comparing differences among segments at a given site, but do not allow quantitative comparisons between sites because of differences in soil moisture, soil texture, and vegetation composition.

Time-lapse photography was used to record the amount and type of ATV traffic passing through each study site.

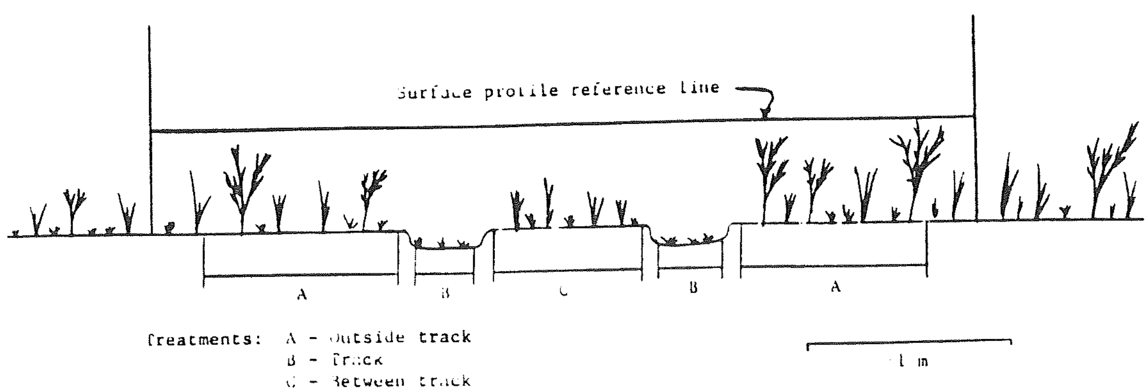

Fig. 3. Cross section of idealized ATV trail showing the placement of surface profile transect and treatment sections.

Table 2. Disturbance rating scale for tracked portions of segments.

Factor	Rating	Disturbance
Vegetation	0	No discernible change.
	1	Slight compression - leaves of stems temporarily bent or rearranged (can barely perceive ATV passage).
	2	Compression - mosses, graminoids, herbaceous species mostly flattened, shrubs becoming compressed.
	3	Tearing and removal of leaves or tearing and displacement of mosses or lichens; or flattening, breakage, or abrasion. or woody stems of branches.
	4	>10-25% of the original composition is not recognizable.
	5	>25-50% of the original composition is not recognizable.
	6	>50-75% of the original composition is not recognizable.
	7	>75-100% of the original composition is not recognizable.
Soil (peat, organic or mineral	0	No discernible change.
	1	>0-5% exposed.
	2	>5-10% exposed.
	3	>10-25% exposed.
	4	>25-50% exposed.
	5	>50-75% exposed.
	6	>75-90% exposed.
	7	>90-100% exposed.
Topography (micro)	0	No discernible change.
	1	Track depression <2.5 cm for <50% of the track length, or slight compression evident on individual tussocks or hummocks.*
	2	Track depression <2.5 cm for >50% of the track length, or slight to moderate tussock or hummock compression.*
	3	Track depression >2.5-5 cm for >50% of the track length, or moderate tussock or hummock compression.*
	4	Track depression >5-10 cm for >50% of the track length, or moderate to severe tussock or hummock compression.*
	5	Track depression >10-15 cm for >50% of the track length, or severe tussock or hummock compression.*

Table 2. Continued.

Factor	Rating	Disturbance
	6	Track depression >15-20 cm for 50% of the track length, or severe tussock or hummock compression to destruction.*
	7	Track depression >20 cm for >50% of the track length, or tussocks or hummocks destroyed.*

*Tussock/hummock compression:

- Slight --sedge stems flattened or missing on tops of individual tussocks; hummocks compressed less than 25% of their original height.
- Moderate --compression so that trail is evident but tussocks or hummocks are compressed less than 50% of their original height.
- Severe --compression is evident for the entire length of the trail and tussocks and hummocks are compressed greater than 50% of their original height.
- Destroyed --tussocks or hummocks are flattened.

Intervalometers were used to control battery-operated super 8 mm motion picture cameras equipped with zoom lenses. Kodak Ektachrome Type G, ASA 160, film was used. Single exposures were made every three or six minutes depending upon the field of view afforded at a given site and field logistics. The interval chosen for a particular site was presumed adequate for capturing the passage of an ATV on at least one frame before it left the field of view. At these rates a single 50 ft roll of film (3600 frames) lasted either 7.5 days or 15 days. Accordingly, film and batteries for each system were changed weekly or biweekly. Each system was housed in a clear acrylic resin box to which was added a bag containing approximately 50 g of silica gel desiccant. Each frame of movie film was later examined under 10-45X magnification for the presence of vehicles.

Baseline information concerning the extent of ATV trails in the area before seasonal use began in 1986 was documented using color infra-red aerial photography (approximately 1:7000 scale). These photographs will be compared with others taken during the summer of 1987 to note possible changes and will be the subject of a separate report.

Data Analysis

Surface profile data obtained on different dates for each transect were adjusted prior to statistical analysis. Adjustments were necessary because transect marker positions shifted over time due to frost-heaving, changing permafrost thaw depths, and other factors beyond our control. Extensive graphing of profiles and overlaying of the graphs were necessary to align transects measured at different times horizontally to the nearest 0.5 cm. The reference height for each transect cord was determined by averaging the first and last five surface profile transect measurements. Values for the remaining transect intervals were then subtracted from the reference height to establish the height of each interval along the surface profile.

Surface profile data from the three transects for each site segment (new, established, or recovery) were pooled for the following statistical comparisons.

1. For each measurement date, surface profile elevations of the three treatments (tracks, between tracks, and outside the tracks) within each transect were compared employing a one-way analysis of variance and Duncan's multiple range

test to evaluate differences.

2. Surface profile elevations were compared among dates measured for each of the three treatments per transect (tracks, between tracks, and outside the tracks), using a one-way analysis of variance and Duncan's multiple range test.

3. New segment surface profile elevation data from the last date sampled in 1986 were compared with similar data collected only once during 1987 using an independent samples t-test to determine possible changes from one year to the next. Data for 1987 were obtained from only eight of the thirteen original sites.

Means were considered significantly different at the 0.05 level of probability. All dates reported are 1986 unless stated otherwise.

RESULTS

Twenty-eight vehicles were photographed during the summer using the time-lapse technique. Three vehicles were photographed going to and returning from their trip destination on the same day, therefore, the photographs represent 25 separate round-trips. Photographic and other evidence (Kunz [1986]?) suggest that the intervals between exposures were excessive and, as a result, some vehicles passed undetected. Film coverage of the sites was incomplete due to a number of other reasons which included low temperatures; weak or dead storage cells; overexposure of film; fog, rain, or snow obscuring the lens;

entire systems being overturned by animals; and failure to set all camera and intervalometer switches in the correct positions.

Had the cameras functioned properly throughout the summer, a factor based upon the ratio of vehicles photographed traveling both to and from a destination through a given site to that of vehicles photographed at the site traveling only to or from a destination could have been derived to help correct for the extended time interval and thus provided an estimate of the actual number of ATV trips. Because this was impossible, the assumption was made that the interval to capture every ATV passage in at least one frame should have been just half of that used, an assumption that may still underestimate the actual number of trips. A second correction factor was applied to the number of recorded trips for each site based upon the success ratio of the camera at a given site. This factor overestimates the number of trips because the failure rate was greater during periods of inclement weather and at night, both times of cooler temperatures and reduced traffic. An estimate of the number of trips made was derived by multiplying the number of trips documented on film by the correction factors. By adding the estimated number to the reported number of trips that were not also documented on film, a minimum probable number of round-trips through the site during the summer was calculated.

Coverage and frequency values for vascular species present at each study site are listed in Appendices A and B, and lichens identified at each study site are given in Appendix C.

Akmagolik-1

The natural vegetation at this site formed a willow-sedge shrub tundra community dominated by a Salix planifolia-S. reticulata-Carex bigelowii association. Dryas integrifolia and C. membranacea were also common in the understory, mosses were abundant, and lichens were common locally. In disturbed areas (tracks) a sedge-willow tundra community dominated by a C. bigelowii-S. planifolia association developed. Compared to control plots, coverage in the tracks on established and recovery segments was reduced 43 percent for low shrubs, 62 percent for dwarf shrubs, 25 percent for forbs, 30 percent for graminoids, 63 percent for mosses, and 98 percent for lichens.

Surface profiles and disturbance ratings for the recovery segment of the trail were obtained three times between 15 July and 13 August. Tracks were significantly deeper than between track and outside track (control) treatments, and the between track treatment was significantly deeper than the outside track treatment. This relationship did not change during the measuring period. More than 75 percent of the plants growing in the tracks were readily identifiable when first documented on 15 July, but by 13 August less than 25 percent of the species were recognizable. During the same period the amount of exposed soil in the track changed from less than 10 percent to more than 75 percent. Depth of the ruts averaged 10 cm over more than half of the segment (Fig.3).

Established segment surface profiles were measured only on 31 July. Track and between track treatments on the segment were

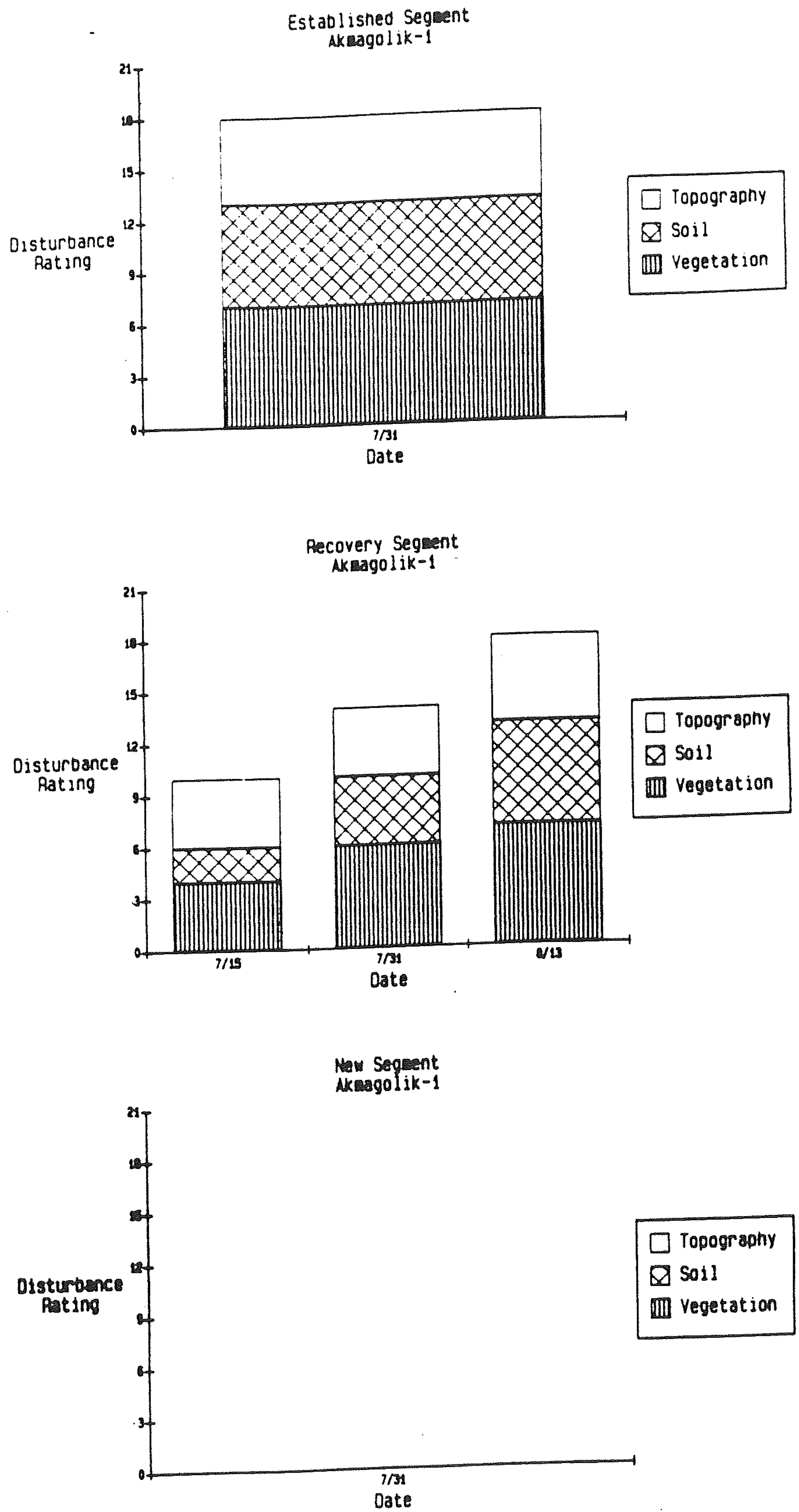

Fig. 3. Cumulative disturbance ratings, Akmagolik-1.

significantly deeper than control portions of transects. Disturbance ratings obtained on this date indicated that more than 75 percent of the original vegetation composition in the tracks was not recognizable, soil was exposed over more than 75 percent of the track, and tracks were more than 10 cm deep over more than 50 percent of the segment (Fig. 3).

Surface profile data were not obtained for the new segment and no disturbance was evident when rated on 31 July.

The camera system operated satisfactorily for the first 11 days after installation on 30 June, after which the camera light-metering system failed. For the remainder of the summer the film was over-exposed to the extent that nothing was discernible. No vehicles were recorded on film at this site, however, four round-trips with Argos were reported into the area during the summer (Kunz [1986]?).

Akmagolik-2

A *Dryas integrifolia*-*Carex bigelowii* association dominated the dryas-sedge dwarf shrub tundra community that characterized this site. *Salix reticulata* and *Eriophorum* spp. were also common components of the community, as were mosses. Coverage by *C. aquatilis* growing in disturbed, wet areas (tracks) increased substantially when compared with controls, while that by *D. integrifolia* was reduced by more than half to 27 percent, thus changing the character of the vegetation to a sedge-dryas tundra community. Lichens were scarce on the disturbed portions.

Disturbance ratings were recorded for the recovery segment on 15 July and for all segments on 30 July (Fig. 4). No disturbance was apparent on the new segment, and there was but little change between the two dates on the recovery segment. Cumulative disturbance ratings for the recovery and established segments were similar, but not as severe as the respective segments at Akmagolik-1. ATV traffic avoided test segments at this site during the summer by using an alternate, parallel route.

Surface profiles were measured on 15 July, 30 July, and 12 August on the recovery segment. On all three dates track treatments were significantly deeper than between track treatments, and between track treatments were significantly deeper than outside track treatments. No significant changes in the profiles occurred over time during the four-week sampling period.

Established segment surface profiles were measured on 30 July. Tracks and between track treatments were significantly deeper than outside treatments on the established segment. The new segment was also bypassed by vehicles, therefore, there was no evidence of change in the surface profiles due to ATV use. The time-lapse camera functioned 71 percent of the time between 30 June and 7 September. Four round-trips involving Argos were reported into the area during the summer (Kunz [1986]?), however, no vehicles were recorded on film at this site.

Anaktuvuk-1

The natural vegetation at this site formed a dryas-lichen

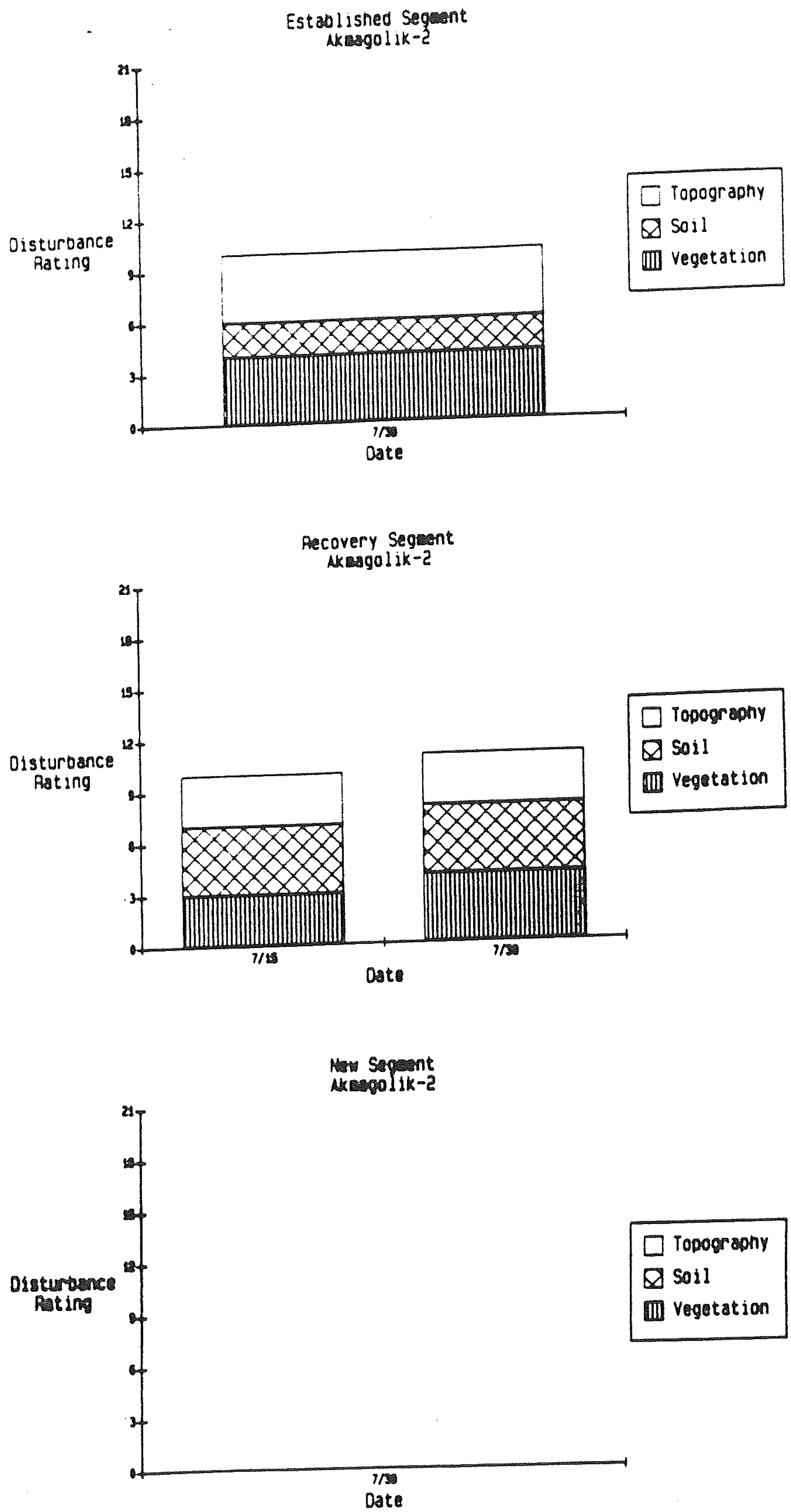

Fig. 4. Cumulative disturbance ratings, Akmagolik-2.

dwarf shrub tundra community which was dominated by a Dryas integrifolia-Equisetum spp.-moss-lichen association. Lichens included Cetraria spp. (especially C. cucullata), Cladonia sp., and Cladina spp. Carex spp. and Equisetum spp. were also substantial components of the community. In the tracks coverage by dwarf shrubs, lichens, and mosses decreased 37, 96, and 33 percent, respectively, when compared with undisturbed treatments, while that of graminoids (primarily Carex spp.) increased 29 percent. The vegetation trend on disturbed portions of this site was towards a sedge-dryas tundra community.

Disturbance at this relatively dry site was rated on 29 July and 8 September (Fig 5). Tire ruts on established and recovery segments averaged about 2.5 cm deep. The amount of track with exposed soil decreased from over 75 percent on 29 July to less than 25 percent by 8 September for both established and recovery segments. It was obvious that residents had frequently avoided the study segments by using alternate routes. By the end of the season, tracks were noticeable on the new segment where tires had crushed lichens, compressed sedges, and torn some mosses. Track depression was apparent on less than half of the new segment and measured less than 2.5 cm deep. Soil was exposed in the tracks for less than half the segment's length. When revisited in August 1987 no recovery was observed of either the microtopography or the vegetation, however, exposed soil was no longer obvious.

By early September tracks on the new section were deeper than both the between track and outside track portions of the

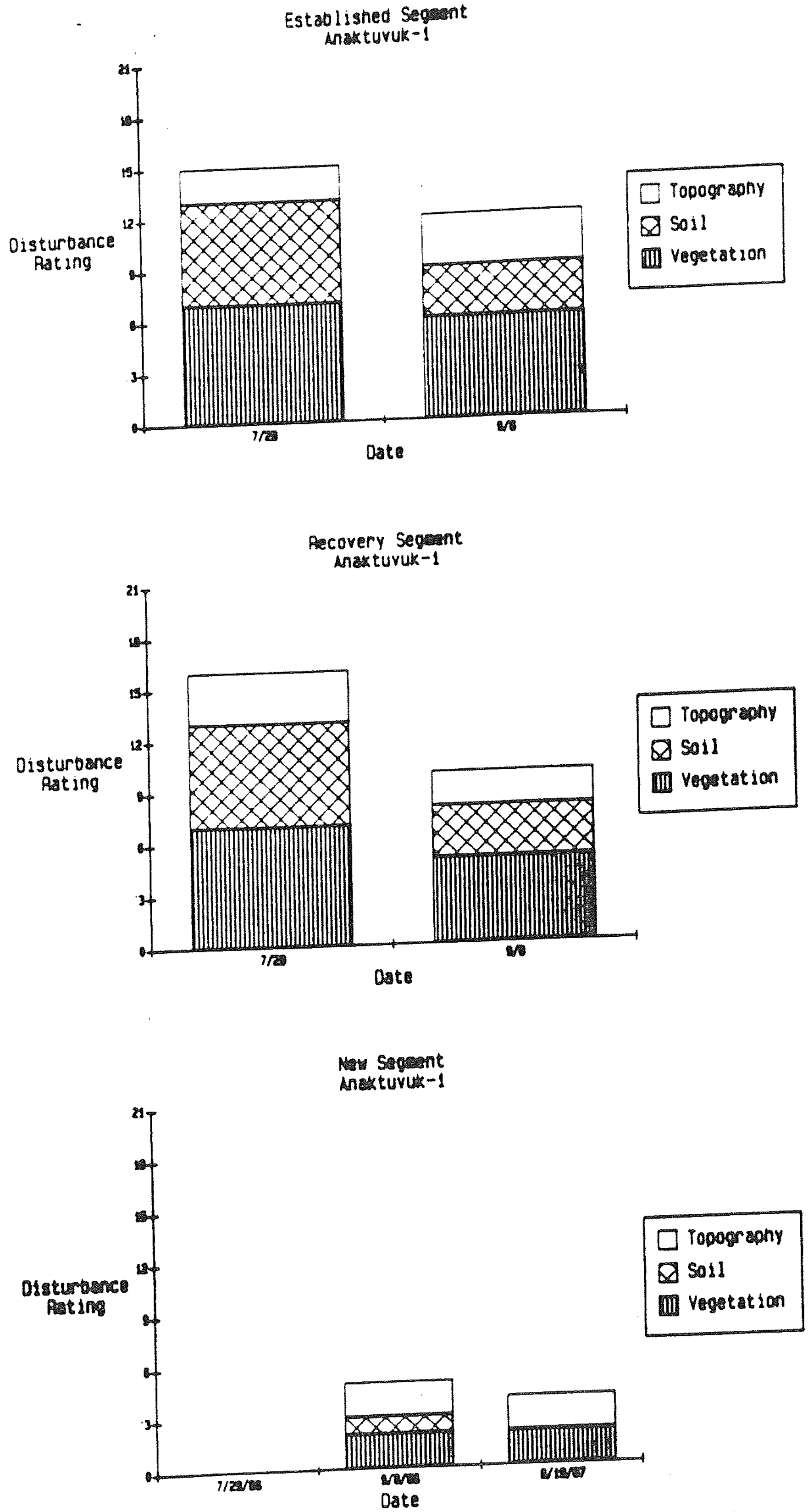

Fig. 5. Cumulative disturbance ratings, Anaktuvuk-1.

transects. Surface profiles of outside track treatments were significantly higher than both track and between track treatments when measured on 24 June for the recovery segment, and on 29 July and 19 August for the established segment. By the end of July track treatments were deeper than between track treatments, and between track treatments were deeper than outside track treatments on the recovery section. After one year, track treatments on the new section were significantly higher than when last measured in 1986, but still deeper than in June or July 1986.

Examination of time-lapse photography showed that the camera was functional 68 percent of the time between 14 July and 21 September. Two vehicles were photographed on the site during that time period. One vehicle was a red Argo photographed on 6 September and the other was a green Argo photographed on 8 September. At least two other Argos passed the site undetected and were photographed together in one frame on 13 September at Anaktuvuk-3. Six trips were estimated during this period by application of the correction factors to the two recorded events. Eleven vehicles were reported to have made trips into this area during the summer (Kunz [1986]?). None of the reported trips coincided with the dates on which vehicles were photographed although seven of them occurred during the period the camera was in place. According to information from all sources, 15 and perhaps as many as 17 round-trips were made through the site during the summer.

Anaktuvuk-2

The vegetation community at this site was a dryas-lichen dwarf shrub type characterized by a Dryas integrifolia-lichen association. Vaccinium uliginosum and Carex spp. were abundant, and lichens included Cetraria cucullata, C. islandica, C. nivalis, Masonhalea richardsonii, Cladina uncinalis, C. mitis, Cladonia spp., Conicularia spp., and Thamnolia spp. Species growing on disturbed portions were representative of a sedge-dryas community type. Shrub coverage decreased 59 percent while that by mosses and lichens decreased 80 and 96 percent, respectively, on disturbed portions when compared with controls.

As late as 5 August there was no discernible change in disturbance to vegetation between the track and the control treatments on the new segment (Fig. 6). By 15 September mosses and lichens were compressed and sometimes displaced by ATV traffic. Exposed soil and slight depression of the microtopography were also evident. Eleven months later compressed vegetation and surface depression were still apparent in the tracks on the new segment. Cumulative disturbance ratings for established and recovery segments showed a similar pattern of increase throughout the summer.

Surface profiles were measured three times during the summer field season on each of the segments. Track treatments on the new segment were significantly deeper than the outside track on 24 June and significantly deeper than both outside and between track treatments on 5 August and 15 September. However, these differences were no longer evident when measured in 1987. Track

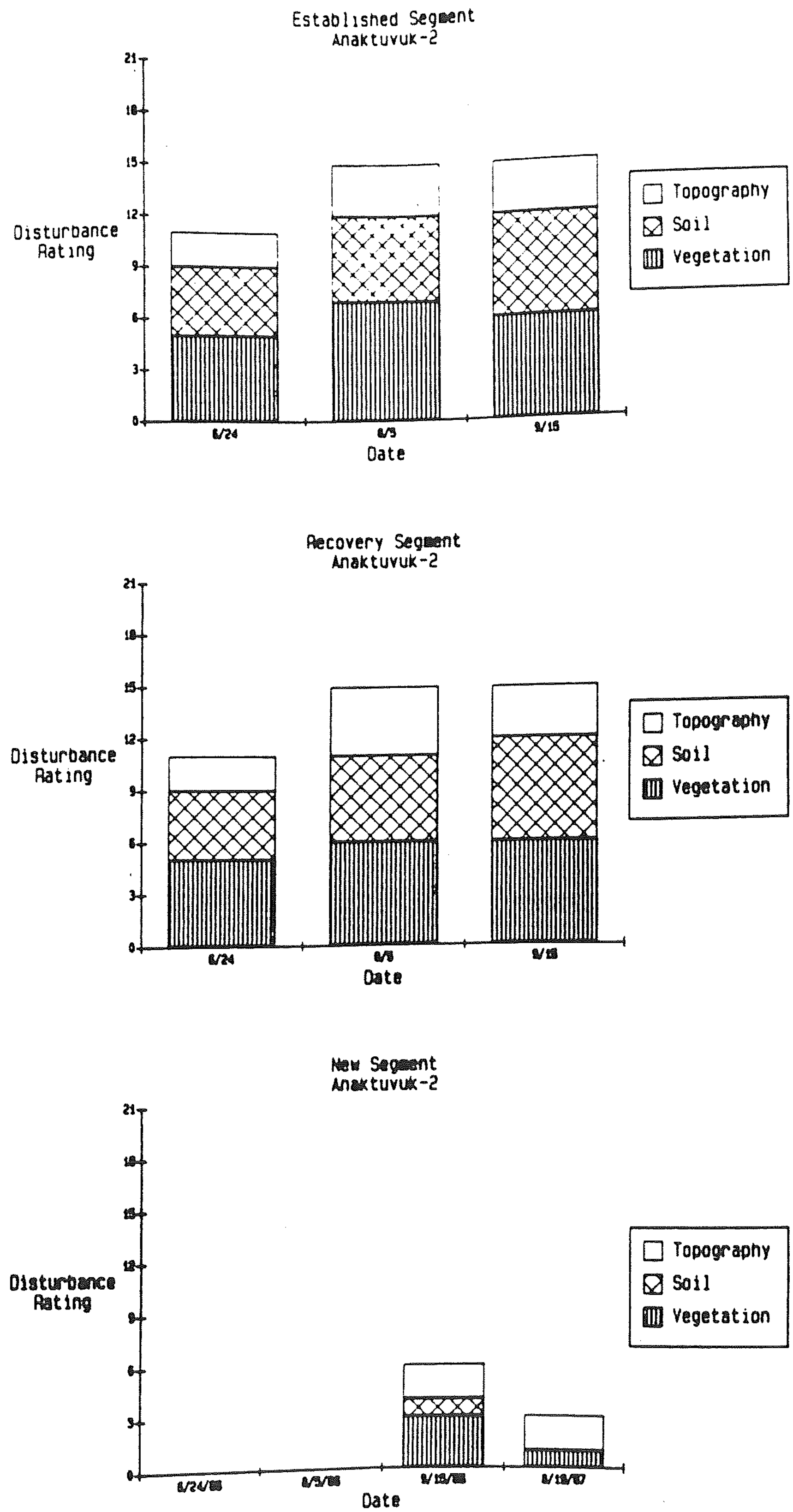

Fig. 6. Cumulative disturbance ratings, Anaktuvuk-2.

treatments on the recovery segment were consistently deeper than both outside track and between track treatments. On the established segment, track treatments were significantly deeper than between track treatments, and between track treatments were significantly lower than controls throughout the summer.

The camera operated successfully 60 percent of the time between 30 June and 21 September at this site. No vehicles were recorded on film, although two were photographed at Anaktuvuk-3 and had to first pass this site. It is not known how many of the 11 reported trips to the Anaktuvuk River area (Kunz [1986]?) traveled this far.

Anaktuvuk-3

The vegetation at this site formed a dryas-sedge dwarf shrub community dominated by a *Dryas integrifolia*-*Carex bigelowii* association. *Rhododendron lapponicum*, *Arctostaphylos alpina*, *Carex membranacea*, *C. aquatalis*, and *Eriophorum vaginatum* were also common. Total coverage on disturbed portions was two-thirds that of the control area and showed a trend towards a sedge-dryas tundra community type. Lichens were absent in the tracks and coverage by mosses was less than 20 percent of that present on undisturbed portions of the segment.

The topographic disturbance rating for the established segment increased slightly between 25 June and 5 August due to deepening of tire ruts (Fig. 7). During the same period, the cumulative disturbance rating for the recovery segment showed a slight decrease because of new plant growth and reduced soil exposure. The only disturbance observed on the new segment in

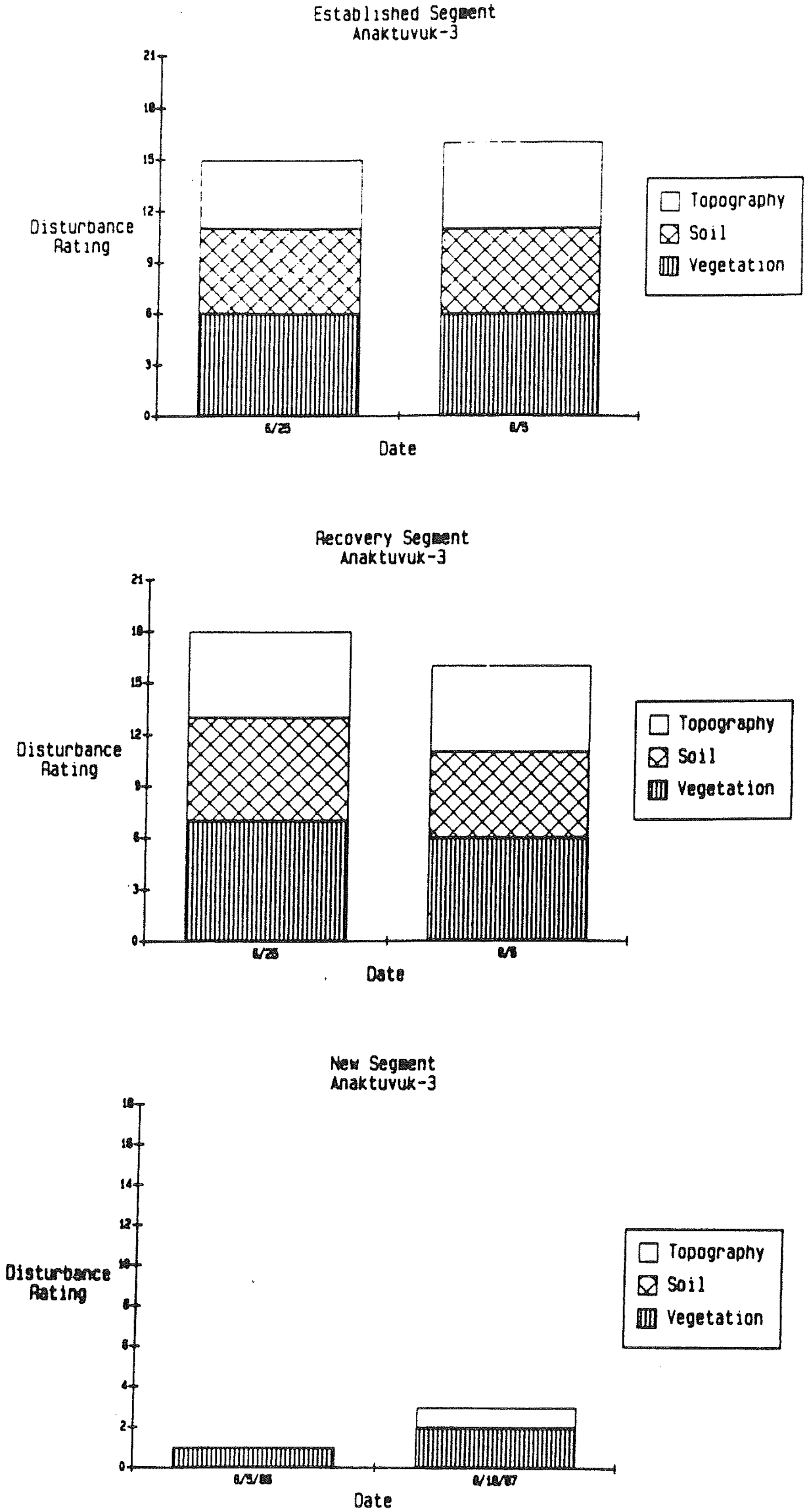

Fig. 7. Cumulative disturbance ratings, Anaktuvuk-3.

1986 was on 5 August, when plants appeared slightly compressed from the passage of ATV traffic. One year later it was apparent from the more pronounced compression of vegetation and exposure of soil that the new segment had received use after 5 August 1986.

There were no significant differences in surface profile depths for any of the treatments on the new segment between 25 June 1986 and 19 August 1987. Established and recovery segments displayed the typical pattern of track treatments being significantly deeper than between track treatments which were significantly deeper than outside track treatments when measured on 25 June and 5 August. In addition, both track and between track treatments for the established segment were significantly deeper in August than in June.

The camera was functional 46 percent of the time between 30 June and 21 September. The only vehicles photographed were two Argos in one frame on 13 September. Application of the correction factor for this site to the two known events yielded an estimate of nine vehicles passing through the site during this period. None of the 11 reported trips coincided with either of the recorded trips, therefore, at least 13 trips were made assuming that all of the reported trips traveled as far as this site. The estimated and reported trips taken collectively suggest that 20 vehicles may have made round-trips through this site during the summer.

Contact-1

Vegetation at this site formed a dryas-sedge dwarf shrub tundra community type dominated by a *Dryas integrifolia*-*Salix reticulata*-*Carex bigelowii* association. Mosses were common and included *Aulocomnium palustre*, *Pleurozium schreberi*, *Dicranum* sp., *Rhytidium rugosum*, and *Tomenthypnum nitens*. Lichens, although sparse, were represented by *Cetraria cucullata*, *Dactylina arctica*, *Masonhalea richarsonii*, and *Stereocaulon* sp. Other species common in the understory included *Salix arctica* and *Pedicularis langsdorffii*. The site was surrounded by an open low willow shrub community dominated by a *Salix glauca*-*Arctogrostis latifolia* association. Disturbed portions were dominated by *Carex* spp. and mosses. Coverage contributed by *Dryas integrifolia* and *Salix reticulata* on disturbed portions of the segment was reduced to 89 percent that of the controls.

Cumulative disturbance ratings for the established segment did not change during the summer, but a slight increase was noted on the recovery segment between 11 July and 29 August (Fig. 8). The new segment was first used by an Argo on 3 July. When first rated on 11 July, the microtopography and vegetation of the new segment showed but slight effects from use by ATV traffic. By 29 August, species recognition was impossible for more than 25 percent of the plants growing in the ATV tracks, surface depression was more extensive, and some soil had become exposed. One year later only the surface depression caused by tires was evident on the new segment.

Track treatments on the new segment were significantly

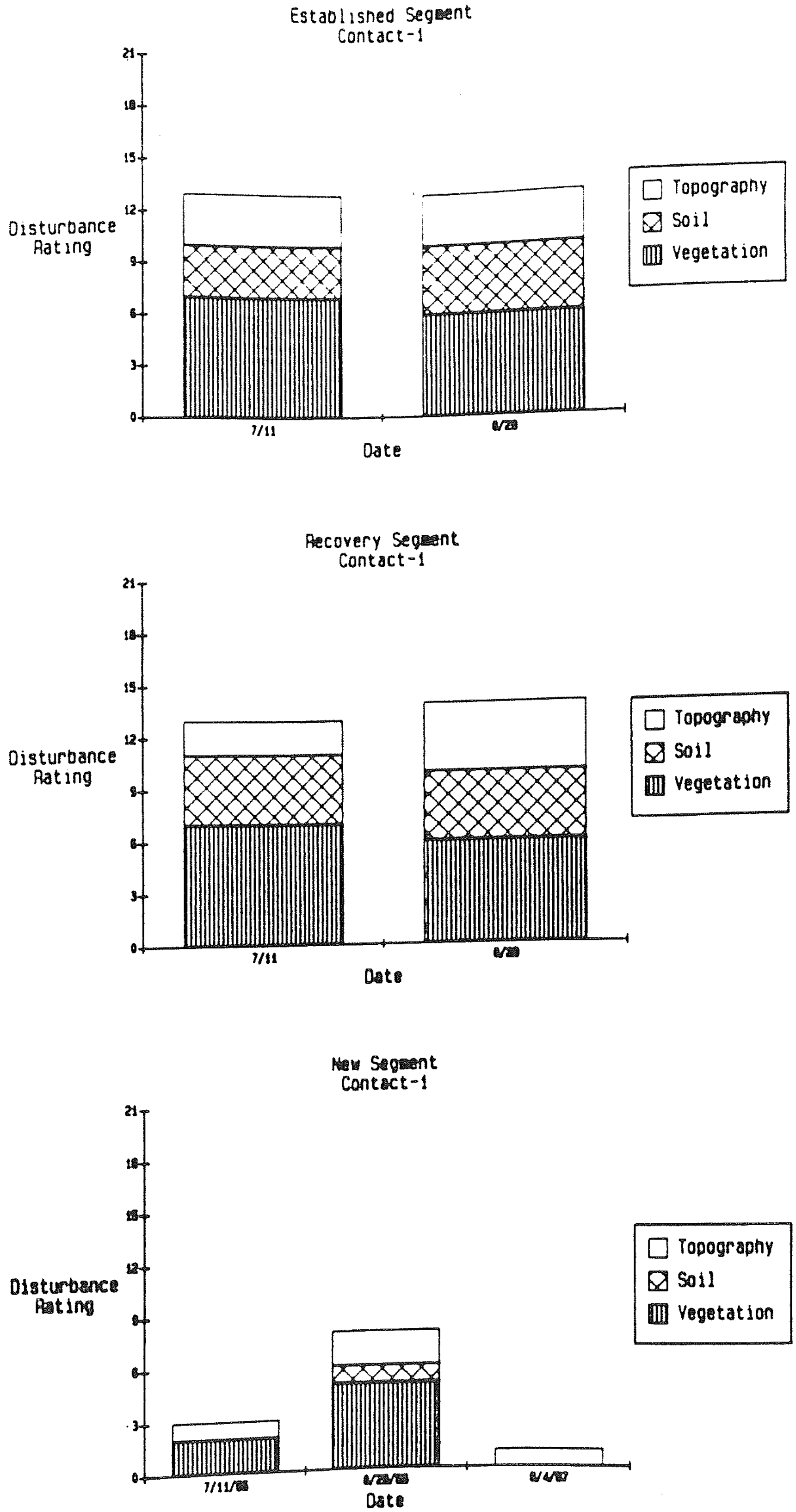

Fig. 8. Cumulative disturbance ratings, Contact-1.August

deeper than either between track or outside track treatments by 25 July and remained so through 4 August 1987. Established and recovery segments were measured six times each between 18 June and 15 September. The track and between track treatments were significantly deeper than the outside track treatments for the recovery segment. On the established segment, track treatments were significantly deeper than between track treatments which were deeper than outside treatment.

The time-lapse camera functioned 59 percent of the time at this site between 6 July and 14 September. Nine vehicles were photographed during the summer. In one instance a vehicle was photographed twice on the same day (traveling opposite directions) making eight the minimum number of round-trips recorded by the camera at this site. In addition, an Argo passed this site undetected but was photographed on 17 September at Contact-2. With the exception of one three-wheeled all-terrain cycle, all of the vehicles photographed in the Contact drainage were either six- or eight-wheeled Argos. Application of the correction factors for this site to the eight recorded trips suggests that 27 round trips were made during the period the camera was in place. Two reported trips into the Contact drainage occurred on 3 July and 21 September (Kunz [1986]?), dates not covered by the time-lapse camera. Taking into consideration information from all sources, 11 confirmed, and perhaps as many as 29 round-trips occurred during the summer.

Contact-2

Vegetation at this site formed a dyras-sedge dwarf shrub tundra community type dominated by a Dryas integrifolia-Carex spp. association. Salix arctica and mosses were abundant, while lichens were scarce. Total shrub coverage was reduced 89 percent on disturbed areas, and coverage by graminoids and mosses was reduced 77 and 51 percent respectively in comparison with controls. What little vegetation that remained in the tracks was dominated by Carex species.

Disturbance was rated five times between 16 June and 19 August (Fig. 9). Cumulative disturbance ratings increased slightly during the summer on the established segment but underwent little change on the recovery segment. Vegetation in the tracks on the new segment was compressed by 9 July, and evidence of tearing and leaf removal was observed on 23 July. By 19 August track depth exceeded 2.5 cm over more than half the length of the segment, some soil was exposed, and more than 75 percent of the plants growing in the tracks were not recognizable by species. One year later the condition of vegetation had improved slightly, but microtopography and soil disturbance remained unchanged.

Track treatments on the new segment were significantly deeper than outside track and between track treatments when measured on four successive occasions between 9 July 1986 and 19 August 1987. Between track treatments on the new segment were significantly deeper in 1987 than at any time in 1986. Established and recovery segment profiles were obtained five

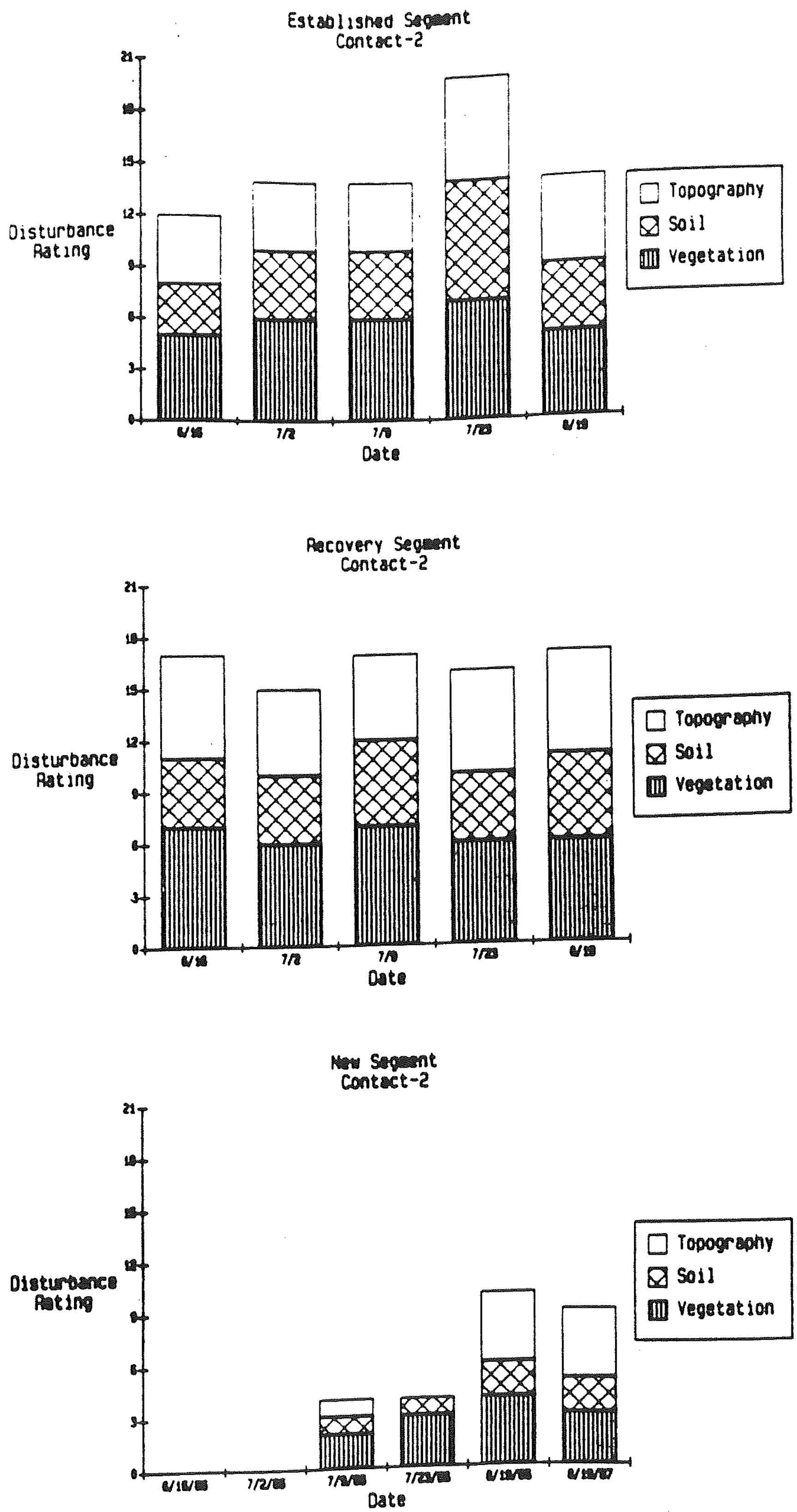

Fig. 9. Cumulative disturbance ratings, Contact-2.

times between 16 June and 19 August 1986. Track and between track treatments on the established segment were significantly deeper than controls, while tracks were significantly deeper than between track treatments which were deeper than outside track controls on the recovery segment.

The camera functioned 49 percent of the time between 30 June and 21 September. The only ATV known to have passed this site was photographed on 17 September. Four round-trips were estimated to have passed this site during the summer by application of the correction factors to the single known case. At least 3 round-trips were actually made if the two reported trips for the Contact drainage (Kunz [1986]?) are considered in addition to the photographed ATV.

Contact-3

The vegetation at this site formed a dryas dwarf shrub tundra community dominated by *Dryas integrifolia*. Another dwarf shrub, *Salix reticulata*, was common, as were mosses and lichens (especially *Cetraria cucullata* and *Stereocaulon* spp.). There was no perceptible change in total coverage by dwarf shrubs or graminoids on disturbed areas, however, a pronounced reduction from 45 percent to 1 percent occurred in lichen coverage. Forb and moss coverage also decreased appreciably on disturbed sites.

Obvious compression of vegetation and some surface depression by ATV tires were evident on the new segment by 10 July. Exposure of soil in the tire tracks was first noticed on 24 July and by 20 August surface depression had increased both in depth and extent. One year later soil exposure was not obvious, but slight compression of the vegetation and track depression was still visible. Little change was apparent in the condition of vegetation or soil exposure on the recovery segment throughout the summer of 1986, however, more than half the length of tracks on recovery and established segments increased in depth from less than 2.5 cm in June to more than 5 cm to 10 cm by 20 August. The cumulative disturbance rating for the established segment increased 50 percent between 16 June and 20 August (Fig. 10).

All segments were measured 5 times between 16 June and 20 August. By 10 July track treatments were significantly deeper than adjacent outside track and between track treatments on the new segment. There was no change when measured again on 19 August 1987. This relationship held for the recovery segment throughout the summer of 1986, while track treatments for the established segment were deeper than between track treatments which were deeper than outside track treatments. The between track treatments on the new segment were significantly deeper in 1987 than in 1986.

The camera operated 54 percent of the time between 30 June and 21 September. No vehicles were photographed, but it was obvious that the site had been used during the summer.

Giant-1

An open low willow shrub community dominated by a *Salix glauca*-*Hylocomium splendens* association best describes the vegetation at this site, although the sampled willow coverage

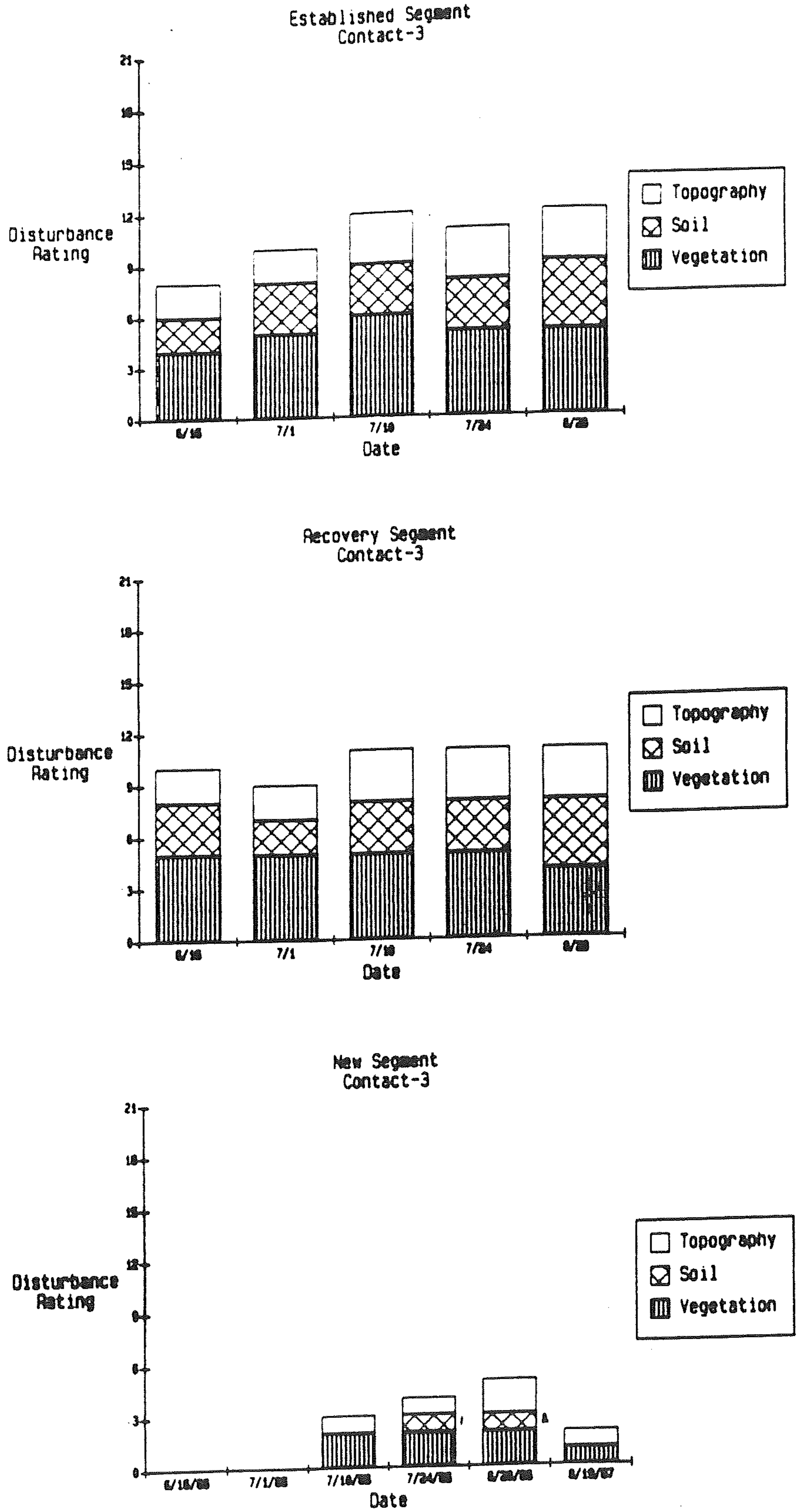

Fig. 10. Cumulative disturbance ratings, Contact-3.

was slightly less than 25 percent. Other common shrubs included _Salix reticulata_ and _Betula nana_, which was similar in growth form to _S. reticulata_. _Equisetum scirpoides_ and _Pedicularis langsdorffii_ were common herbaceous plants, _Aulocomnium turgidum_ and _Tomenthypnum nitens_ were other mosses, and important lichens included _Cetraria cucullata_, _C. islandica_, and _Dactylina arctica_. In disturbed areas coverage by shrubs and graminoids was reduced by more than half, that of forbs by two-thirds, and lichens were all but eliminated. Only the mosses showed no pronounced change in coverage.

Mosses growing on the new segment were mostly flattened in the tracks by 9 September. By 3 August 1987 evidence of ATV passage from the previous year was barely perceptible on the new segment. Little change was noticeable throughout the summer in he degree of disturbance on established and recovery segments (Fig. 11). Alternate routes were used by ATV operators to avoid portions of, or all, segments at this site.

Surface profiles were measured five times during the summer of 1986 at this site. The track treatment on the new segment was not significantly different from the outside treatment until early August, although the tracks were deeper than the center (betweeen treatment) beginning with the first measurement made in mid-June. The August 1986 relationship held when profiles were again measured on the new segment in 1987. For the recovery segment, track treatments were significantly deeper than center treatments which were significantly deeper than outside treatments throughout the summer. On the established segment

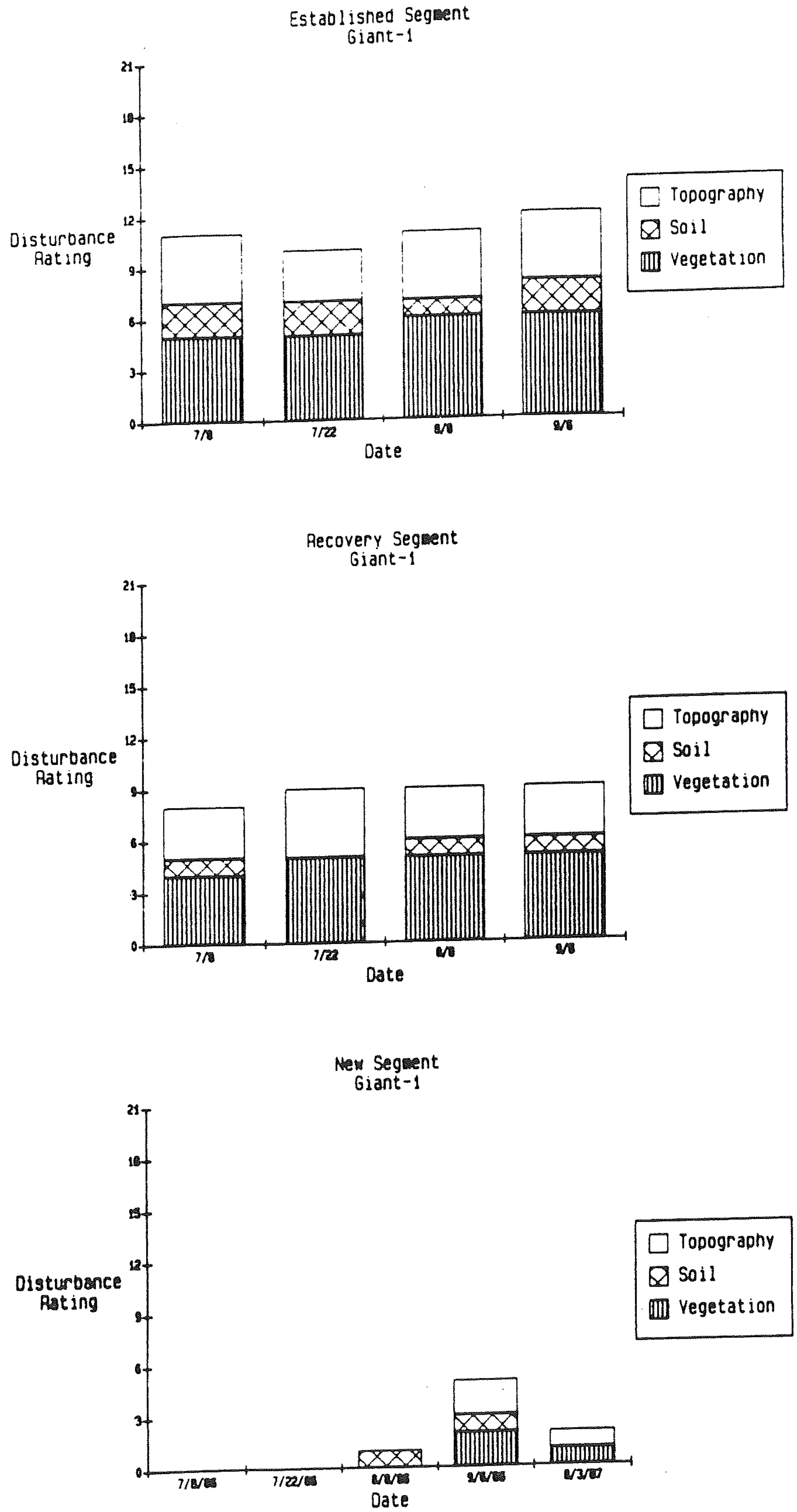

Fig. 11. Cumulative disturbance ratings, Giant-1.

track treatments were deeper than either center or outside treatments throughout the summer with the exception of the last measurement made on 9 September when differences were no longer significant.

The time-lapse camera functioned 33 percent of the time between 7 July and 21 September but no vehicles were photographed at this site. Six round-trips by one or more six-wheeled argos were reported in the Giant drainage during July and August (Kunz [1986]?). Two round-trips are known to have been made between 21 and 25 August from tracks observed in fresh snow.

Giant-2

Vegetation at this site was characterized by an open low mixed shrub-sedge tussock tundra community dominated by an *Eriophorum vaginatum-Carex-bigelowii-Betula nana-Ledum palustre-Vaccinium vitis-idaea* association. Other common woody plants included *Cassiope tetragona*, *Salix planifolia*, *Vaccinium uliginosum*, and *Empetrum nigrum*. Although forbs were scarce, *Petasites frigidus* and *Polygonum bistorta* were present. Mosses included *Aulacomnium turgidum*, *Hylocomium splendens*, *Dicranum* sp., *Polytrichum* sp., and *Sphagnum* sp., and lichens such as *Cetraria cucullata*, *Cladina rangeriferina*, *Dactylania arctica*, *Platismatia glauca*, and *Thamnolia subliformis* were common. Disturbed areas were dominated by *Carex bigelowii* and *Eriophorum vaginatum*, however, coverage by graminoids was reduced by nearly half that of undisturbed control areas. Cover by woody plants in the tracks was reduced 90 percent and that of mosses 85 percent in comparison with controls. Dwarf shrubs and forbs were eliminated, and lichens nearly eliminated, in the tracks.

Slight compression of plants due to ATV traffic was noticeable on the new segment during first week in August and was more severe one month later (Fig. 12). When examined again in August 1987, plants growing in tracks on the new segment were flattened, and the track depth was less than 2.5 cm for more than half the segment's length. Established and recovery segments remained virtually unchanged throughout the summer of 1986. Four alternate routes allowed much of the ATV traffic to avoid the test segments at this site.

Surface profiles for the new, established, and recovery segments were measured five times during the 1986 field season at this site. New segment track and outside track treatments were initially deeper than the center treatment. By September the track treatment was significantly deeper than the outside treatment which was still significantly deeper than the center treatment. When measured again on 3 August 1987 the track treatment was significantly deeper than either the outside or center treatments. For the established segment, track treatments were significantly deeper than between track treatments which were significantly deeper than outside track treatments throughout the summer. On the recovery segment, both track and treatments were significantly deeper than the outside treatment, a relationship that persisted during the summer.

The camera functioned satisfactorily only 10 percent of the time between 30 June and 21 September. No vehicles were

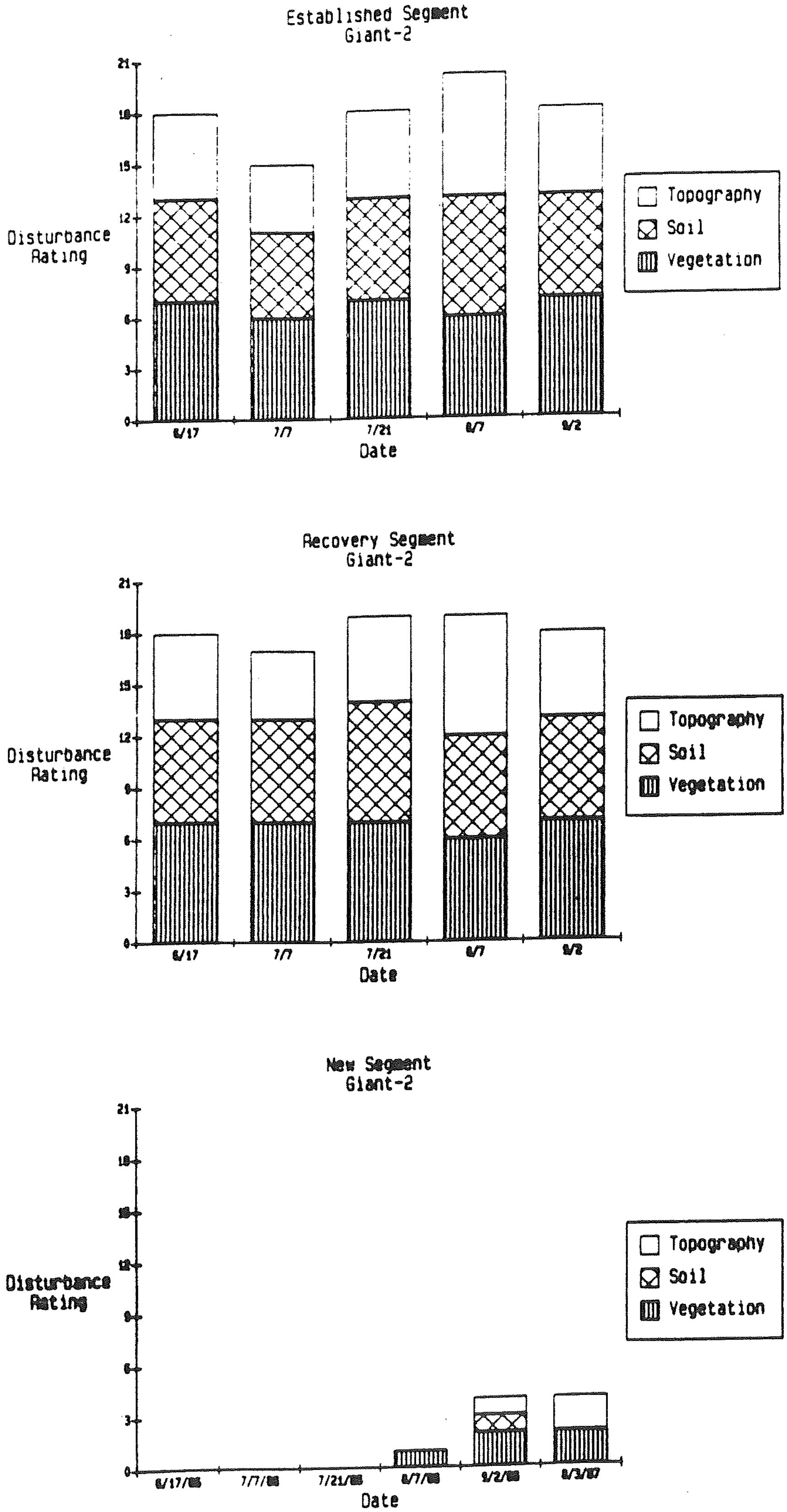

Fig. 12. Cumulative disturbance ratings, Giant-2.

photographed at this site. In addition to battery failure, the lens of the camera was out of focus for much of the summer. Six round-trips were reported into the Giant drainage by one or more six-wheeled Argos during July and August (Kunz [1986]?). Tracks left in fresh snow indicate that two round-trips with Argos occurred between 21-25 August.

Kongumavik-1

A *Dryas integrifolia*-*Salix reticulata*-*Carex* spp. association was dominant in this dryas-sedge dwarf shrub tundra community. Mosses were common, as were lichens such as *Cetraria cucullata*, *C. islandica*, *Dactylina arctica*, and *Thamnolia* sp.

On disturbed areas, which were largely devoid of vegetation, total plant cover was only 16 percent of that for control areas. By 17 July some of the vegetation on the new segment was slightly compressed from ATV traffic (Fig. 13). Surface depression caused by ATV tires was less than 2.5 cm for less than half the segment, and soil was exposed in less than 5 percent of the tracks. For both the established and recovery segments, tracks were 2.5-5.0 cm deep for over half their length, more than 75 percent of the original vegetation was altered beyond recognition, and soil was exposed over 75-90 percent of the tracks. By mid-August the tracks had deepened to at least 10 cm over more than half the recovery segment's length, and soil was exposed in at least 90 percent of the track. No changes were apparent on the established segment during the summer. The disturbance rating for the recovery segment increased slightly over the summer as a

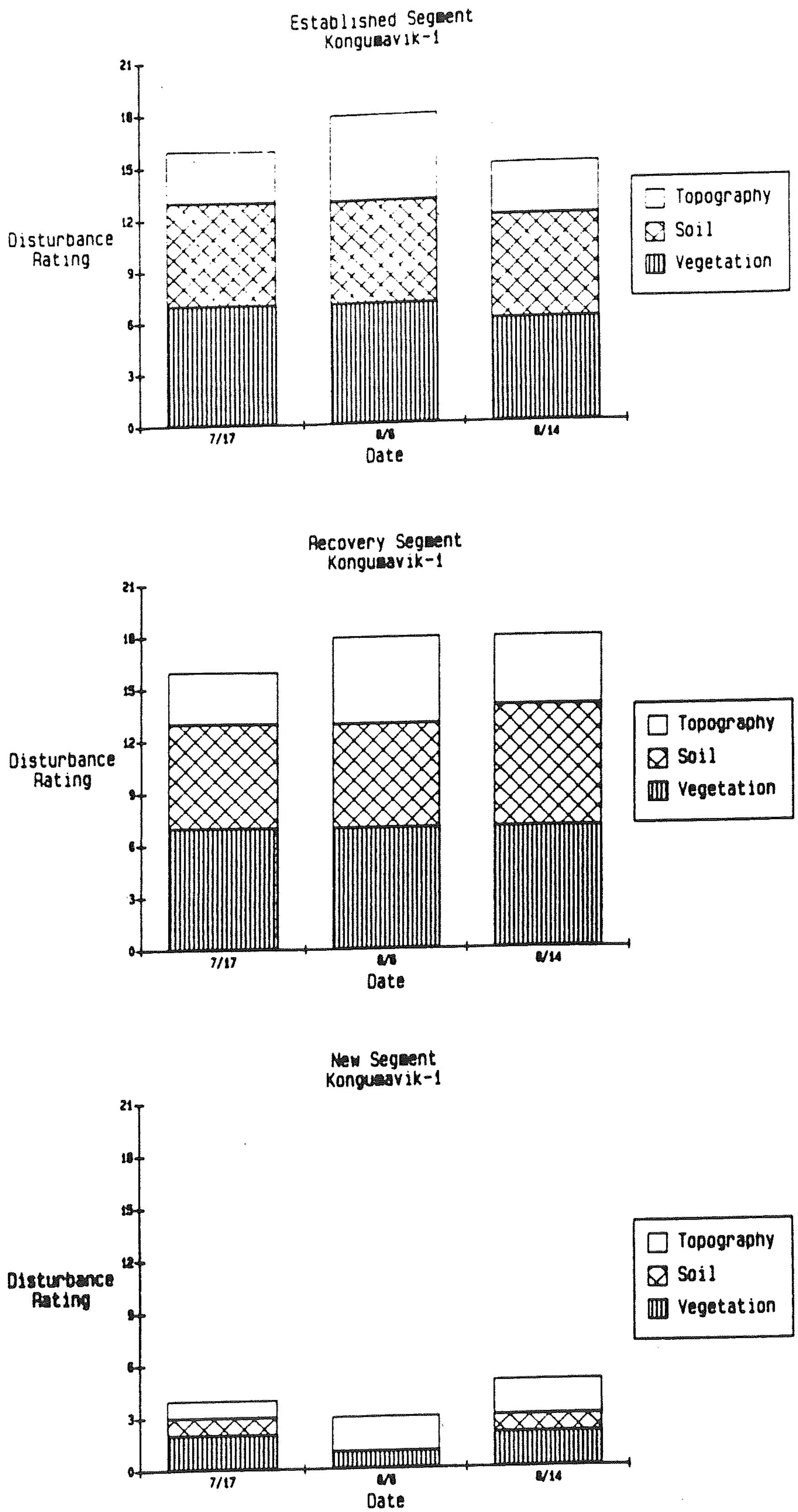

Fig. 13. Cumulative disturbance ratings, Kongumavik-1.

result of deepening tire ruts and additional soil exposure. Alternate routes were also used at this site. One set of tracks bisected the new segment while another set paralleled it. Both alternate routes paralleled the established segment.

When soil profiles were first measured on 19 June, track and between track treatments were significantly deeper than the outside treatments on new, established, and recovery segments. This relationship was stable throughout the summer on the new and established segments, but by 17 July track treatments on the the recovery segment were significantly deeper than between track treatments which were significantly deeper than outside treatments.

The camera was in place between 30 June and 21 September at this site, but there was no coverage from 28 July through 10 August due to missing film. During the time for which data exist, the camera operated successfully 53 percent of the time and two Argos were photographed. Application of the correction factors suggest that eight round-trips were made during the period of camera coverage. Five trips were reported for the summer (Kunz [1986]?), none of which coincided with the two recorded passages. The five reported trips occurred between 16 July and 16 August. An additional trip was observed by project field personnel on 16 July (M. Emers and H. McClain, personal communication). These data imply that between 8 and 14 Argos made round-trips through this site during the summer.

Kongumavik-2

This site was vegetated by a dryas-sedge dwarf shrub tundra community dominated by a *Dryas integrifolia*-*Salix phlebophyla*-*Carex* spp. association. *Salix reticulata* was also common, mosses were abundant, and foliose lichens (*Peltigera* sp. and *Nephroma* sp.) were more profuse than fruticose lichens (*Cetraria cucullata*, *C. islandica*, *Thamnolia* sp., and *Dactylina arctica*). Total coverage by vegetation established on disturbed areas was but 30 percent of that on non-disturbed portions of the segments. Lichens were practically eliminated in areas disturbed by ATV use.

Vegetation growing on the new segment showed no signs of disturbance when observed in mid-July (Fig. 14). Slight compression of leaves and stems was noted by 6 August, and one week later most of the plants that had been driven over were flattened. Little or no surface depression or soil disturbance was observed on the new segment.

More than 75 percent of the original plant composition in the tracks was not recognizable throughout the summer on the established and recovery segments (Fig. 14). More than 50 percent of the track surface was exposed on both of these segments by mid-July. On the established segment, exposed soil increased to more than 75 percent by the first week in August, but no change was observed on the recovery segment. When first observed in July, tracks on the recovery segment were 5-10 cm deep, but increased to 10-15 cm deep by mid-August. Track depth on the established segment increased from 10-15 cm in mid-July to

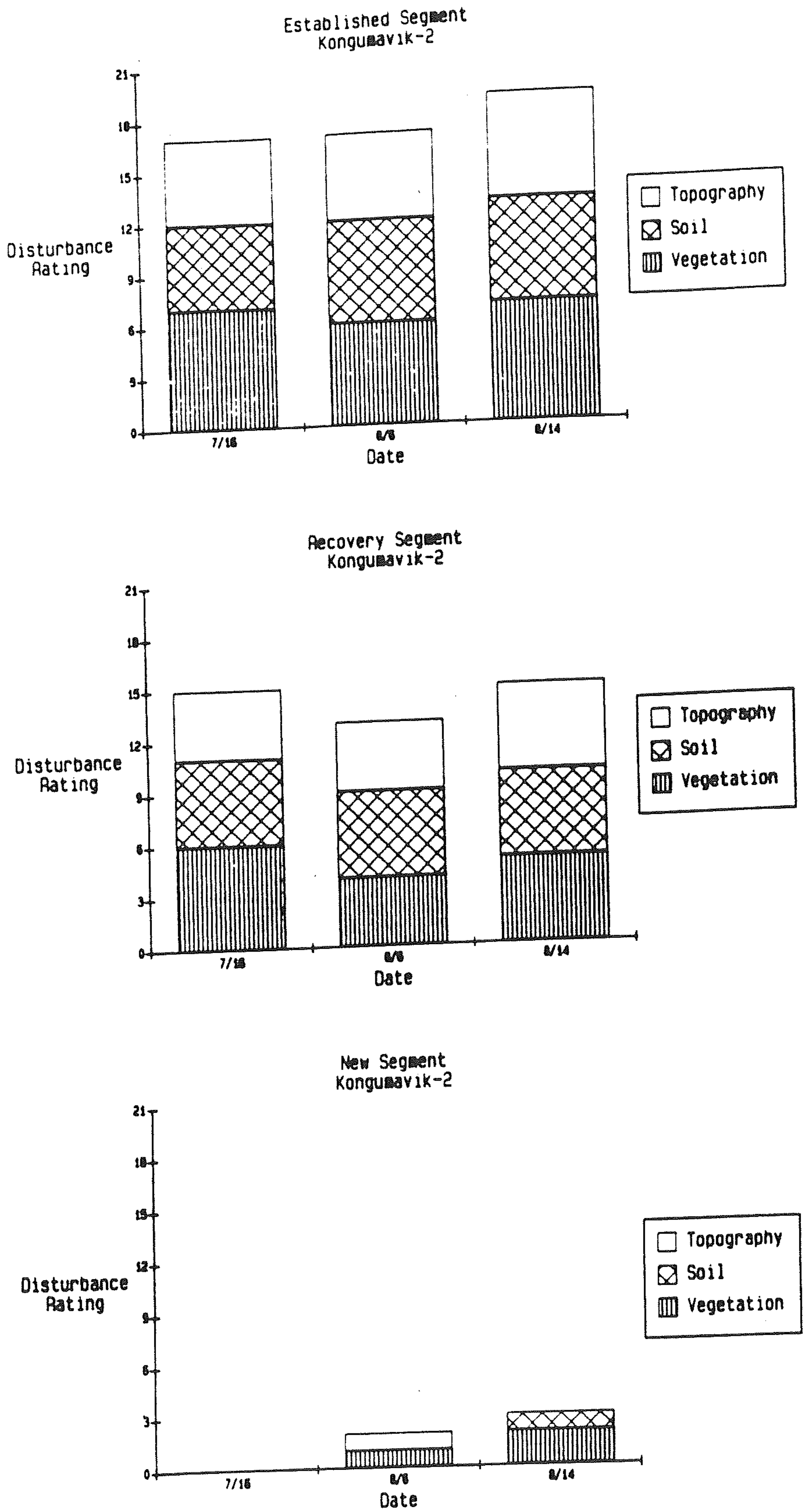

Fig. 14. Cumulative disturbance ratings, Kongumavik-2.

15-20 cm by mid-August.

Track and between track treatments on the new segment were significantly deeper than outside track treatments. For the recovery and established segments, track treatments were significantly deeper than between track treatments which were significantly deeper than outside treatments. These relationships persisted throughout the summer.

The camera operated 49 percent of the time between 30 June and 8 September. No vehicles were photographed. Five vehicles were reported to have made trips through this site during the summer (Kunz [1986]?) and an unreported Argo was observed on 16 July by project field personnel (M. Emers and H. McClain, personal communication). Two trails parallel to the established segment and one trail parallel to the new and recovery segments were also used by vehicles during the summer.

Kollutarak-1

This dryas dwarf shrub community was dominated by *Dryas octopetala*. Lichens were common in the community and mosses were also present. Forbs and graminoids provided little cover.

Disturbance ratings for all segments increased markedly between 12 August and 22 September mainly due to the compression of vascular plants (*Dryas octopetala* and *Oxytropis nigrens*) and lichens, and the exposure and displacement of gravel and soil (Fig 15). Eleven months later soil exposed on the new segment from the previous year's ATV traffic was difficult to differentiate from undisturbed bare soil. Compressed vegetation

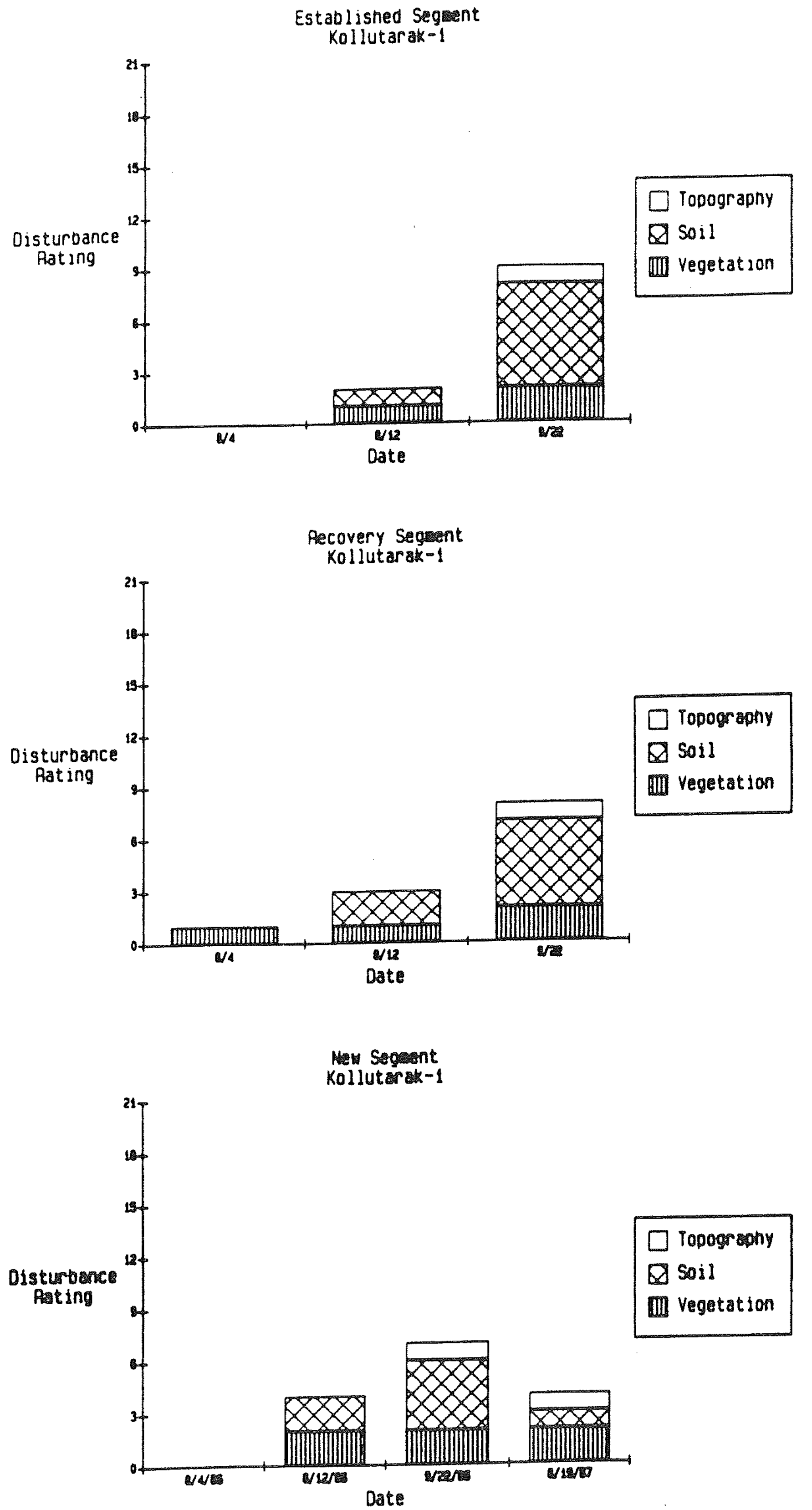

Fig. 15. Cumulative disturbance ratings, Kollutarak-1.

and surface depression caused by ATV traffic were still evident.

Segments were not used as intended, thus rendering this site meaningless for most purposes of this study. Alternate routes were traveled that paralleled or bisected the study segments. In addition, marker stakes were flattened.

The camera functioned 48 percent of the time. Twelve Argos, only ten of which are believed to represent separate trips, were filmed. An estimated forty-two round-trips were derived by applying the site correction factors to the ten recorded round-trips. Sixteen round-trips, all by eight-wheeled Argos, were reported during the summer (Kunz [1986]?). None of the reported trips coincided with trips recorded on film, therefore, at least of 26 trips were made into the Kollutarak drainage during the summer.

DISCUSSION

By early July ATV use had begun in the lower, snow-free portions of the Anaktuvuk, Contact, Giant, and Kongumavik drainages. Use spread into the Kollutarak drainage by late July and through the Kongumavik into the Akmagolik drainage by early August. No ATV use in the Akmagolik or Kongumavik drainages was reported after mid-August, nor in the Giant drainage after August. Use occurred in all other study areas through at least late September. The heaviest ATV use took place during the months of August and September.

Tracks resulted from compression or displacement of vegetation and soil by ATV tires. On established and recovery segments, both track and between track portions of surface profile transects were deeper than control portions of the transect. Vegetation growing in the trail between the tracks was subjected to breakage or removal, especially as the tracks deepened, due to the low ground clearance of Argos. The use of snowmobiles on many of the trails also resulted in breakage and removal of plants, and flattening of the area between the tracks. Other studies have reported on the susceptibility of shrub species to physical damage or breakage from snowmobile traffic, especially when the compacted snow cover was not deep enough to protect them (Neumann and Merriam 1972, Wanek 1973).

Disturbance ratings, as well as the depth of tracks, increased on established segments over the summer as a result of additional ATV traffic. Recovery segments receiving no additional use during the summer remained the same or showed slight recovery, primarily due to graminoid growth. Disturbance and surface profile depression where tire tracks occurred were apparent on new segments that experienced ATV traffic. A few inconsistencies in the data resulted because some of the new segments were not used, some of the recovery segments were used, and some of the established segments were avoided by vehicle operators. On several occasions, disturbance caused by the passage of a single ATV was obvious after segments were bisected, entirely bypassed, or otherwise inappropriately used by the driver.

Stakes placed to route ATV traffic around recovery segments and onto new segments were removed at the end of the 1986 field season for safety reasons by National Park Service employees. When the new segments were examined in 1987, it was often difficult to distinguish between soil that became exposed due to ATV traffic the previous year from naturally bare ground. Track depths on new segments did not change significantly between the end of the 1986 field season and August 1987 with the exception of the tracks at ANA-1 whose depth was less in 1987.

The passage of a single ATV was not without effect upon the vegetation. In addition to errant paths taken through treatment segments that were noted above, routes taken by Argos travelling "cross-country" near KON-2 left trails of compressed sedges and crushed Equisetum arvense (M. Emers, personal communication). Stems or branches of shrubs, especially those of Betula nana, Vaccinium uliginosum, Salix glauca, S. pulchra, and S. alexensis, were prone to abrasion and breakage by ATV traffic. Mosses and graminoids were relatively resistant to ATV traffic, but subject to flattening, shearing, or displacement, particularly as a result of a vehicle sliding or making a turn. It was observed that lichens, when dry and brittle, were especially susceptible to breakage and one pass by an ATV all but eliminated them in its tracks. Others have reported that tundra vegetation is always injured by off-road vehicles, however, the injury sustained from a single pass is usually slight to moderate and the plants usually recover with no long-term effect (Sparrow et al. 1978, Wooding and Sparrow 1979).

With repeated ATV use plants become crushed or broken until it is difficult or impossible to identify them in the field.

When the organic mat was not broken, destruction of shrubs and lichens was often followed by an increase in the importance of several species of graminoids. Grasses are usually the first plants to re-invade drier tundra sites, while sedges are generally the first to revegetate wet tundra sites (Bliss and Wein 1972, Chapin and Shaver 1981, Sparrow et al. 1978, Wooding and Sparrow 1979). On portions of established and recovery segments we observed an increase in cover contributed by some forbs, notably _Epilobium_ sp., _Equisetum scirpoides_, _E. varigatum_, _Papaver_ sp., _Polygonum bistortoides_, _P. viviparum_, _Saussurea angustifolia_, _Stellaria_ sp., and _Thalictrum alpinum_.

Crushed plant remains decompose and release nutrients more rapidly than the adjacent undisturbed vegetation, thus a green strip of vegetation is produced that contrasts with the drabber-appearing brownish tundra resulting from the accumulation of several years of standing plant remains (Brown 1976, Challinor and Gersper 1975). When the disturbance was limited to vegetation damage and depression of the surface, tundra usually recovered to near its original state in a few years, except for the obvious green plants growing in the vehicle tracks (Abele et al. 1984, Chapin and Chapin 1980). When shearing or destruction of the organic mat occurred, revegetation of disturbed areas was prevented due to subsidence and erosion (Gersper and Challinor 1975, Abele et al. 1984). According to Mellor (1980), regardless of whether a green belt or a water-filled trough develops, long-lasting visible scars are created which contribute to the visual degradation of aesthetic qualities.

Disturbance that was obvious when viewed from the air was sometimes difficult to detect on the ground. Disturbance induced changes such as a shift in the relative density or cover of plants present in the community (e.g., a dryas-sedge tundra type transformed to a sedge-dryas tundra type) were often subtle when viewed on the ground, but stand out as a bold stripe across the tundra when viewed from the air due to the change in relative composition and the greening effect. Vehicle produced disturbances such as exposed soil and surface depressions were often apparent from the ground as well as from the air.

In general, ATV induced disturbances appeared to be greater on wet sites than on dry ones, but wet sites may become revegetated more rapidly than drier ones. The composition of newly established vegetation is typically not consistent with that of the pre-disturbance plant community and decades may be required to attain equilibrium with the surrounding community. This is true especially for lichens and to a lesser extent for shrubs.

The least damaging and most easily reversed disturbance occurs when stream beds are utilized for ATV routes. Outwash plains and old river terraces, because of their gravelly nature and good drainage, are also quite resistant to surface perturbations. There may be long-term effects, however, on the vegetation. Poorly drained wet terrain should always be avoided, especially fine textured soils, as a single pass by an ATV can leave a deeply rutted path with uprooted and abraded or broken plants. Habitats that are normally dry to moist are more susceptible to disturbance during rainy periods or wetter than normal summers.

Continued or expanded ATV use in the vicinity of Anaktuvuk Pass will result in additional long-term disturbance to the vegetation and terrain. Routes chosen by ATV operators are usually along paths of least resistance. Tall and low shrub vegetation types are normally avoided in favor of dwarf shrub types, and tussock tundra and wet sedge meadows are usually avoided if drier habitats can be used. Inevitably some moist or wet ground that is susceptible to rutting must be traversed. Long-term environmental damage will result if the upper permafrost melts and subsidence occurs. As rutted areas are subjected to additional use or subsidence, the ruts may deepen until the trail becomes impassible. Parallel trails become established to detour the impassible sections. Abandoned portions do not recover before the new parallel trails are also abandoned, consequently, the process repeats itself, resulting in an ever widening trail.

If ATV use is permitted to continue, as is intended, within a designated area inside the park boundary, means of minimizing degradation of existing trails should be investigated. Methods for hardening problem portions of trails need to be evaluated. If such an approach proves to be practical, it would help minimize the area of degradation and lessen the visual intrusion that results from ATV use by discouraging the establishment of detours or the formation of new trails around impassible portions.

SUMMARY

Effects of ATV use on surface profiles, vegetation, soil exposure, and topography were studied on established, recovery, and new segments of trails originating from Anaktuvuk Pass, Alaska, a village located in Gates of the Arctic National Park.

Surface profile transects indicated that track treatments were significantly deeper than outside track treatments on all established segments. At GIA-1 and KON-2 the track treatments were deeper than either the between track or outside track treatments. The between track treatment was also significantly deeper than outside track (control) treatments on transects at ANA-2, ANA-3, CON-1, CON-3, and GIA-2. Tracks and between track treatments of transects at AKM-1, AKM-2, ANA-1, CON-2, and KON-1 did not differ significantly from each other but were significantly deeper than the corresponding controls. At GIA-1 the track alone was significantly deeper than either between track or the control from mid-June through early August, but by early September no significant difference was apparent between any of the treatments.

Track treatments were significantly deeper than outside track treatments on the recovery segment for each study site. In addition, between track treatments were significantly deeper than the controls, but more shallow than the tracks throughout the summer at AKM-1, ANA-3, CON-2, GIA-1, and KON-1. At ANA-2 and CON-3 there were no significant differences between outside track and between track treatments. Track and between track treatments were not significantly different in June at ANA-1, CON-1, GIA-2,

and KON-2. Beginning in July and for the rest of the summer, all treatments differed significantly at ANA-1 and KON-2, while no significant changes occurred at CON-1 or GIA-2.

Track treatments changed significantly during the 1985 field season on new segments at ANA-2, CON-1, CON-3, GIA-1, and GIA-2 by becoming deeper than either between track or outside track treatments. There were no significant changes throughout the 1986 field season on new segments located at ANA-1, ANA-3, CON-2, KON-1, and KON-2.

Recovery segments were opened for vehicle use and new segments were abandoned at the end of the 1986 season. Where transects could be repeated, surface profiles were measured again on new segments in August 1987. Only at ANA-1 was a change observed. The tracks at this site were deeper in September 1986 than in August 1987. No significant changes occurred in the track treatments during the same period on new segments at ANA-2, ANA-3, CON-1, CON-2, CON-3, GIA-1, and GIA-2.

Disturbance ratings increased during the summer for established trails that continued to receive ATV use. Recovery segments receiving no ATV use over the summer showed little change in disturbance ratings. Ratings of disturbance increased for new segments that received ATV use during the summer, however, all but the wettest sites showed some recovery after 11 months of non-use. By far most of the recovery on these lightly used segments was seen in the vegetation component.

The time-lapse camera system operated about 50 percent of the time. Correlation between the numbers and times of reported

ATV trips and those documented on film was poor, and we were unable to relate our observed effects of ATV use to known intensities of use.

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Appendix A
Mean Coverage by Species (% cover). Control data from 30 plots and disturbed data from 12 plots, each 20 x 50-cm size.

	Kollutarak-1		Giant-1		Contact-3		Anaktuvuk-1		Anaktuvuk-2		Contact-1		Kongumavik-1		Kongumavik-2		Contact-2		Akmagolik-2		Anaktuvuk-3		Akmagolik-1		Giant-2	
	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Distrb	Crtl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb
TALL SHRUB																										
Salix alexensis			0.7																							
LOW SHRUB																										
Salix glauca			11.0	4.4	1.0		7.8		1.3	1.3	5.9	1.7	0.1													
Salix pulchra			4.1	4.0			6.1	4.0	0.5		5.7	2.5	1.6						2.8	4.4	0.1		32.1	10.1	10.6	5.4
DWARF SHRUB																										
Andromeda polifolia																					1.2				0.1	
Arctostaphylos alpina			2.4	0.4			3.2	0.6	1.2		0.5		1.1	0.2			0.6				7.4	0.2				
Betula nana	4.7		0.5		0.1				2.1	0.2															16.0	2.1
Cassiope tetragona			+*						0.6	1.5			0.5		2.3		2.3	1.3						0.2	15.5	
Dryas integrifolia			+		46.1	57.7	44.3	27.5	49.3	22.3	50.5	4.6	41.6	4.4	30.1	4.6	40.1	1.5	56.8	26.7	60.6	5.6	10.7	1.5		
Dryas octopetala	23.2		2.1	1.5									4.2	1.5			7.2									
Empetrum nigrum			+																						5.8	
Ledum palustre																									21.7	
Rhododendron lapponicum									0.8	1.9			0.2				0.1				12.3					
Salix arctica					0.5						4.1		0.5	0.2	5.9	3.5	21.6	4.4	1.3	1.0	1.6	2.3	0.4	0.8		
Salix phlebophylla	7.3		+												21.9	6.9										
Salix reticulata			5.8	1.9	30.2	25.2	10.0	6.3	5.6	2.7	20.3	4.0	12.0	1.7	16.5	0.6	7.9	1.3	11.4	0.8	7.0	4.2	20.3	9.4		
Vaccinium uliginosum				0.2					20.0	6.7			1.1						0.5		0.3				0.2	1.5
Vaccinium vitis-idaea																									19.5	
FORB																										
Androsace chamaejasme									0.3	1.0			0.1													
Anemone narcissiflora	1.1												+		+											
Anemone richardsonii					2.3	1.3																				
Anemone sp.			0.1				0.7	0.2	0.1	0.2			0.5	0.4												
Antennaria friesiana	1.3																									
Arnica lessingii													+													
Aster sibericus					0.2																					
Astragalus alpinus			0.1								0.0	0.2	0.2	0.2												
Astragalus umbellatus			1.5	0.2	5.0	1.3	5.6	2.5	0.5	0.4	7.6		1.5				0.1									
Campanula aurita																										
Cardamine hyperborea					+		1.3			0.2			0.2				2.6	0.0			0.2		0.5	0.4		
Castilleja hyperborea													+				*									
Claytonia sarmentosa																0.2	0.1	0.2								
Draba caesia																			+							
Draba nivalis																			+							
Draba sp.	+												0.1	0.2	0.1											
Dodecatheon frigidum					0.1																					
Epilobium sp.														1.7												
Equisetum arvense					0.1		15.0	7.5			12.6	1.9			0.9	0.2	2.3	1.5								
Equisetum palustre													6.5	1.7			+				1.0					
Equisetum scirpoides			5.7	3.1	5.1	2.3	10.6	1.5	0.0	0.2	1.2	0.4	1.6		0.3	1.0	3.1	0.6	0.2	5.2	5.4	1.0	2.5	3.3		
Equisetum variegatum			1.1	0.4	2.7	4.4	10.9	20.6			5.1	1.7	0.7		0.4	0.2	0.0	0.2	7.1	4.0	1.0	1.9	0.1	0.2		
Gentiana propinqua													0.1				+									
Geum glaciale									0.1	1.3																

	KOL-1	GIA-1		CON-3		AHA-1		AHA-2		CON-1		KOH-1		KOH-2		CON-2		AHH-2		AHA-3		AHH-1		GIA-2
Geum rossii												0.7	0.2											
Hedysarum alpinum				1.0	0.6	2.1	2.5			0.9	0.1													
Lagotis glauca												1.3	0.6	0.4		0.1		0.1		0.7				
Lloydia serotina		+																						
Minuartia arctica	1.0	+							0.2					0.1	0.2									
Minuartia macrocarpa												0.3				0.1								
Oxytropis borealis				0.3											0.2									
Oxytropis maydelliana				2.9	1.0			1.9	2.7	1.9		0.7			0.2									
Oxytropis nigrescens	2.9				0.4	0.2						3.0		0.1										
Oxytropis viscida				0.1	0.2					0.1		0.5												
Papaver spp.				0.3				0.1	1.7			0.1		0.3	0.2	0.2	1.5							
Parrya nudicaulis				0.2				0.1						0.2	0.4	0.8								
Pedicularis lapponica																0.7								
Pedicularis kanei																		+						
Pedicularis sudetica																		+						
Pedicularis spp.		1.0	0.2	4.0	1.0	1.3	0.6	2.3	0.8	1.8		2.3	0.2	1.0	0.2			0.2	0.2	1.3		0.3	0.2	0.6
Petasites frigidus						0.5	0.2			0.3				1.2	0.6									0.2
Phlox sibirica																		+						
Polygonum bistorta	0.1							1.3	4.2			0.2		5.0	0.6	1.5	2.7					0.1		0.4
Polygonum viviparum		0.1	0.2	1.6	0.2	0.4	3.1	0.3	1.5	1.3	1.3	1.3	1.5	1.0	0.6	1.7	1.3	1.5	0.8	1.7	1.7	1.8	1.3	
Potentilla biflora												+												
Pyrola grandiflora				5.0	0.2															0.6	0.2			
Pyrola secunda		0.4	0.4											1.2						0.1				
Pyrola spp.						0.6	0.6											0.8	0.4			2.2	2.7	
Saussurea angustifolia								1.3	3.1			0.3	0.6	1.0	0.6	1.8	0.2			0.1		0.1		
Saxifraga cernua																								
Saxifraga davurica														0.3										
Saxifraga hieracifolia					0.2									0.3										
Saxifraga hirculus														0.1	0.2	0.2				0.1				
Saxifraga punctata														0.5	0.2							0.3		
Saxifraga reflexa																		+						
Saxifraga rivularis														0.1										
Saxifraga serpyllifolia	1.4													0.1										
Saxifraga tricuspidata																				+				
Senecio atropurpureus						1.3		0.1						0.5	0.4			0.2				0.2		
Senecio lugens				0.1																				
Silene acaulis												0.1	0.2											
Stellaria crassifolia																+								
Stellaria monantha		+																						
Stellaria spp.		0.3	0.6	0.8	0.6	0.1	0.4	0.1	0.4	0.2				0.7	0.6			0.1	0.2			0.8	0.8	
Thalictrum alpinum				0.7	0.4	0.2		1.7	4.2			0.8	1.9			0.6	1.7	0.2		0.1	0.4			
Tofieldia coccinea								0.2				0.3	0.4											
Tofieldia pusilla							0.2									0.4				0.4				
Valeriana capitata					0.2			0.1						0.1					0.2					
GRAMINOIDS																								
Arctagrostis latifolia				+		1.3	0.6			5.9	6.5			3.9	2.5	0.6	0.6	0.2		0.1	0.4	0.3		
Bromus pumpellianus				0.2	0.2																			
Calamagrostis canadensis	4.1																							
Festuca altaica		0.4		3.0	1.7																			
Festuca baffinensis												+												
Festuca rubra	0.2																							

	KOL-1	GIA-1		COH-3		AHA-1		AHA-2		COH-1		KOH-1		KOH-2		COH-2		AKH-2		AHA-3		AKH-1		GIA-2	
Hierochloe alpina	0.5																								
Poa alpigena		+																							
Poa arctica	+	0.1	0.2	0.5				0.1		0.1	0.0			0.6	0.2	0.5	0.4					1.1	0.2		
Unidentified grass								0.3	0.6																
Carex aquatilis							0.2				0.2						0.2	0.3	10.6	0.1					
Carex bigelowii		+						0.2		0.5				0.6				0.7		2.3	0.2	5.5	1.0		
Carex membranacea						0.1				0.3	0.2					0.3	0.2		0.2						
Carex microchaeta	+																								
Carex misandra				0.8	0.4			0.1									0.2	+							
Carex mesophila																									
Carex rupestris	+																								
Carex scirpoidea				+				0.4	0.8							0.1				0.1					
Carex spp.	5.0	0.8	0.4	5.8	0.5	20.8	20.1	28.3	29.4	25.5	58.0	11.0	3.8	29.1	12.3	66.8	33.1	47.0	61.9	50.2	41.9	56.1	47.1	20.8	19.4
Eriophorum angustifolium																0.6		0.3			1.3				
Eriophorum scheuchzeri														0.1		+									
Eriophorum vaginatum										1.3		0.8	3.5			1.8		0.7	0.4	0.9		0.8		36.8	10.2
Eriophorum spp.		0.1												10.3	1.7			20.3	0.8	18.9	4.4				
Kobresia myosuroides												+													
Kobresia siberica												+													
Juncus castaneus								+																	
Juncus triglumis																+									
Luzula arctica														0.6											
Luzula confusa		+												0.8	0.2										
Luzula rufescens																									
Luzula tundricola		+																							
Luzula spp.																									
MOSS	15.7	60.2	62.7	66.4	50.4	94.3	33.0	47.0	9.6	93.9	52.1	48.6	4.0	91.1	26.0	67.8	15.6	72.5	76.7	74.6	19.6	88.6	33.1	37.1	5.6
LICHEN	26.5	15.3	1.0	44.8	1.3	30.2	1.3	60.2	3.1	6.8	0.2	23.6		26.3	0.4	4.0	0.2	10.8	2.1	17.5		27.4	0.6	38.0	0.2

* "+" Indicates presence at site but outside plots.

Appendix D
Mean Frequency by Species (% frequency). Control data from 30 plots and disturbed data from 12 plots, each 20 x 50-cm size.

GROWTH FORM	Kollutarak-1		Giant-1		Contact-3		Anaktuvuk-1		Anaktuvuk-2		Contact-1		Kongumavik-1		Kongumavik-2		Contact-2		Akmagolik-2		Anaktuvuk-3		Akmagolik 1		Giant-2	
Species	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Distrb	Crtl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb	Ctrl	Dstrb
TALL SHRUB																										
Salix alexensis			10.0																							
LOW SHRUB																										
Salix glauca			56.7	50.0	6.7		30.0		3.3	8.3	26.7	25.0	3.3													
Salix pulchra			36.7	33.3			36.7	11.0	3.3		20.0	16.7	13.3						16.7	16.7	3.3		80.0	83.3	53.3	58.3
DWARF SHRUB																										
Andromeda polifolia																					30.0				3.3	
Arctostaphylos alpina			16.7	16.7			16.7	25.0	13.3		3.3		20.0	8.3			6.7				70.0	8.3				
Betula nana	10.2		3.3		3.3				16.7	8.3															100.0	83.3
Cassiope tetragona									6.7	16.7			3.3		10.0		23.3	8.3						8.3	96.7	
Dryas integrifolia					96.7	100.0	90.0	100.0	96.7	91.7	100.0	58.3	90.0	50.0	76.7	58.3	80.0	16.7	100.0	83.3	96.7	66.7	63.3	16.7		
Dryas octopetala	72.2		3.3	16.7									6.7	16.7			16.7									
Empetrum nigrum																									66.7	
Ledum palustre																									93.3	
Rhododendron lapponicum									70.0	33.3			6.7				3.3				60.0					
Salix arctica					3.3						20.0		36.7	8.3	56.7	25.0	86.7	50.0	36.7	41.7	30.0	50.0	16.7	33.3		
Salix phlebophylla	28.7														70.0	33.3										
Salix reticulata			50.0	33.3	96.7	100.0	76.7	50.0	66.7	25.0	83.3	75.0	93.3	25.0	66.7	25.0	76.7	50.0	60.0	66.7	66.7	50.0	80.0	58.3		
Vaccinium uliginosum				8.3					73.3	58.3			10.0						3.3		13.3				56.7	58.3
Vaccinium vitis-idaea																									80.0	
FORB																										
Androsace chamaejasme									10.0	41.7			3.3													
Anemone narcissiflora	11.1																									
Anemone richardsonii					40.0	50.0																				
Anemone spp.			3.3				10.0	8.3	3.3	8.3			20.0	16.7												
Antennaria friesiana	23.2																									
Arnica lessingii																										
Aster sibericus					6.7																					
Astragalus alpinus			6.7								13.3	8.3	6.7	8.3												
Astragalus umbellatus			26.7	8.3	83.3	83.3	33.3	16.7	20.0	16.7	73.3		43.3				3.3									
Campanula aurita																										
Cardamine hyperborea							33.3			8.3			6.7				56.7	33.3			6.7		20.0	16.7		
Castilleja hyperborea																										
Claytonia sarmentosa																8.3	3.3	8.3								
Draba caesia																										
Draba nivalis																										
Draba sp.													3.3	8.3	3.3											
Dodecatheon frigidum					3.3																					
Epilobium sp.														25.0												
Equisetum arvense					3.3		76.7	58.3			80.0	75.0			20.0	8.3	10.0	16.7								
Equisetum palustre													50.0	25.0							6.7					
Equisetum scirpoides			80.0	83.3	43.3	50.0	86.7	58.3	13.3	8.3	13.3	16.7	13.3		60.0	41.7	43.3	25.0	53.3	83.3	40.0	41.7	50.0	50.0		
Equisetum variegatum			43.3	16.7	73.3	91.7	86.7	100.0			56.7	66.7	26.7		16.7	8.3	30.0	8.3	90.0	75.0	56.7	15.0	3.3	8.3		
Gentiana propinqua													3.3													
Geum glaciale									3.3	8.3																

	KOL-1	GIA-1		COM-3		ABA-1		ABA-2		COM-1		KOM-1		KOM 2		COM 2		AKN-2		ABA 3		AKN 1		GIA 2
Geum rossii												10.0	8.3											
Hedysarum alpinum				23.4	25.0	33.3	16.7			20.0		3.3												
Lagotis glauca												20.0	25.0	16.7		3.3		3.3		10.0				
Lloydia serotina																								
Minuartia arctica	18.5								8.3					3.3	8.3									
Minuartia macrocarpa												13.3				3.3								
Oxytropis borealis				13.3											8.3									
Oxytropis maydelliana				66.7	41.7			26.7	25.0	26.7		10.0			8.3									
Oxytropis nigrescens	35.2				16.7	6.7						36.7		3.3										
Oxytropis viscida				3.3	8.3					3.3		3.3												
Papaver spp.				10.0				3.3	25.0			3.3		10.0	8.3	6.7	16.7							
Parrya nudicaulis				6.7				3.3						6.7	16.7	33.3								
Pedicularis lapponica																26.7								
Pedicularis kanei																								
Pedicularis sudetica																								
Pedicularis spp.		53.5	8.3	60.0	41.7	33.3	25.0	43.3	33.3	60.0		60.0	8.3	23.3	8.3			6.7	8.3	33.3		10.0	8.3	6.7
Petasites frigidus						3.3	8.3			10.0				30.0	25.0									6.7
Phlox sibirica																								
Polygonum bistorta	1.9							36.7	83.3			6.7		43.3	25.0	26.7	25.0					3.3		16.7
Polygonum viviparum		3.3	8.3	16.7	8.3	16.7	41.7	10.0	58.3	33.3	50.0	53.3	58.3	40.0	25.0	50.0	50.0	43.3	33.3	66.7	25.0	70.0	50.0	
Potentilla biflora																								
Pyrola grandiflora				70.0	8.3															23.3	8.3			
Pyrola secunda		16.7	16.7											46.7						3.3				
Pyrola spp.						23.3	25.0											13.3	16.7			53.3	25.0	
Saussurea angustifolia								36.7	83.3			10.0	25.0	6.7	25.0	6.7	25.0			3.3		3.3		
Saxifraga cernua																								
Saxifraga davurica														16.0										
Saxifraga hieracifolia					8.3									10.0										
Saxifraga hirculus														3.3	8.3	6.7				3.3				
Saxifraga punctata														20.0	8.3							10.0		
Saxifraga reflexa																								
Saxifraga rivularis														3.3										
Saxifraga serpyllifolia	29.6													3.3										
Saxifraga tricuspidata																								
Senecio atropurpureus						16.7		3.3						20.0	16.7			6.7				6.7		
Senecio lugens				0.1																				
Silene acaulis												3.3	8.3											
Stellaria crassifolia																								
Stellaria monantha																								
Stellaria spp.		13.3	25.0	30.0	25.0	3.3	16.7	3.3	16.7	6.7				26.7	25.0			3.3	8.3			30.0	16.7	
Thalictrum alpinum				26.7	16.7	6.7		66.7	83.3			33.3	33.3			23.3	25.0	6.7		3.3	16.7			
Tofieldia coccinea								6.7				13.3	16.7											
Tofieldia pusilla							8.3									16.7				16.7				
Valeriana capitata					8.3			3.3						3.3					8.3					
GRAMINOIDS																								
Arctagrostis latifolia						20.0	25.0			70.0	91.7			40.0	16.7	6.7	25.0	6.7		3.3	16.7	10.0		
Bromus pumpellianus				6.7	8.3																			
Calamagrostis canadensis	27.8																							
Festuca altaica		16.7		36.7	66.7																			
Festuca baffinensis																								
Festuca rubra	4.6																							

	KOL-1	GIA-1		COH-3		ABA-1		ABA-2		COH-1		KOH-1		KOH-2		COH-2		AKH-2		ABA-3		AKH-1		GIA-2	
Hierochloe alpina	11.1																								
Poa alpigena																									
Poa arctica		3.3	8.3	3.3				3.3		3.3	33.3			6.7	8.3	3.3	16.7					26.7	8.3		
Unidentified grass								13.3	16.7																
Carex aquatilis							8.3				8.3						8.3	10.0	25.0	3.3					
Carex bigelowii								6.7		20.0				23.3				26.7		56.7	8.3	73.3	41.7		
Carex membranacea						3.3				13.3	8.3					10.0	8.3								
Carex microchaeta																									
Carex misandra *				16.7	16.7			3.3									8.3								
Carex nesophila																									
Carex rupestris																									
Carex scirpoidea								16.7	33.3							3.3				3.3					
Carex spp.	56.6	13.3	16.7	70.0	91.7	86.9	83.3	96.7	100.0	96.7	91.7	86.7	66.7	93.3	83.3	96.7	91.7	100.0	100.0	96.7	100.0	100.0	100.0	96.7	91.7
Eriophorum angustifolium																6.7		10.0			8.3				
Eriophorum scheuchzeri														3.3											
Eriophorum vaginatum										20.0		33.3	25.0			40.0		26.7	16.7	16.7		16.7		93.3	50.0
Eriophorum spp.		3.3												30.0	25.0			63.3	33.3	70.0	16.7				
Kobresia myosuroides																									
Kobresia sibirica																									
Juncus castaneus																									
Juncus triglumis																									
Luzula arctica														6.7											
Luzula confusa														16.7	8.3										
Luzula rufescens																									
Luzula tundricola																									
Luzula spp.																									
MOSS	81.5	96.7	91.7	76.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	90.0	75.0	100.0	91.7	100.0	66.7	90.0	100.0	100.0	100.0	100.0	91.7	86.7	100.0
LICHEN	90.7	100.0	41.7	100.0	50.0	93.3	50.0	100.0	41.7	70.0	8.3	96.7		86.7	16.7	33.0	8.3	83.3	41.7	93.3		90.0	25.0	90.0	8.3

* "+" indicates presence at site but outside of plots.

Appendix C

Lichens identified at Anaktuvuk Pass ATV sites. "+" indicates presence.

Species	KOL-1	GIA-1	CON-3	ANA-1	ANA-2	CON-1	KON-1	KON-2	CON-2	AKM-2	ANA-3	AKM-1	GIA-2
Asahinea chrysantha	+				+		+	+			+	+	+
Cetraria cucullata	+	+	+	+	+	+	+	+	+	+	+	+	+
Cetraria islandica	+	+	+	+	+		+	+	+	+	+	+	+
Cetraria nivalis	+	+			+	+	+	+		+	+	+	+
Cetraria tilesii							+			+			
Cladina mitis			+		+		+						
Cladina rangiferina													+
Cladina spp.				+									
Cladonia uncialis	+	+	+		+						+		
Cladonia spp.	+	+	+	+	+	+	+			+	+	+	+
Cornicularia spp.	+				+		+						
Dactylina arctica		+	+	+	+	+	+	+		+		+	+
Lecanora epibryon	+	+	+		+	+	+		+				
Masonhalea richardsonii		+	+	+	+	+	+	+		+		+	+
Nephroma spp.								+					
Ochrolechia spp.	+		+				+						
Peltigera aphthosa		+				+							
Peltigera canina	+			+	+	+							
Peltigera spp.			+	+				+		+		+	+
Platismatia glauca													+
Stereocaulon spp.	+	+	+			+	+	+		+		+	
Thamnolia subuliformis													+
Thamnolia spp.	+	+	+		+	+	+	+		+	+	+	